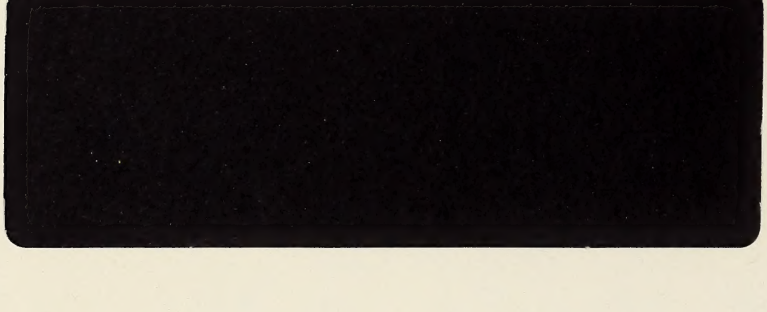
ASSESSMENT OF COST EFFECTIVENESS OF R-2000 ENERGY MEASURES IN THE PRAIRIES

Alberta
MUNICIPAL AFFAIRS
Innovative Housing Grants Program



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August 1989

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The Program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, energy conservation, site and subdivision design, site servicing technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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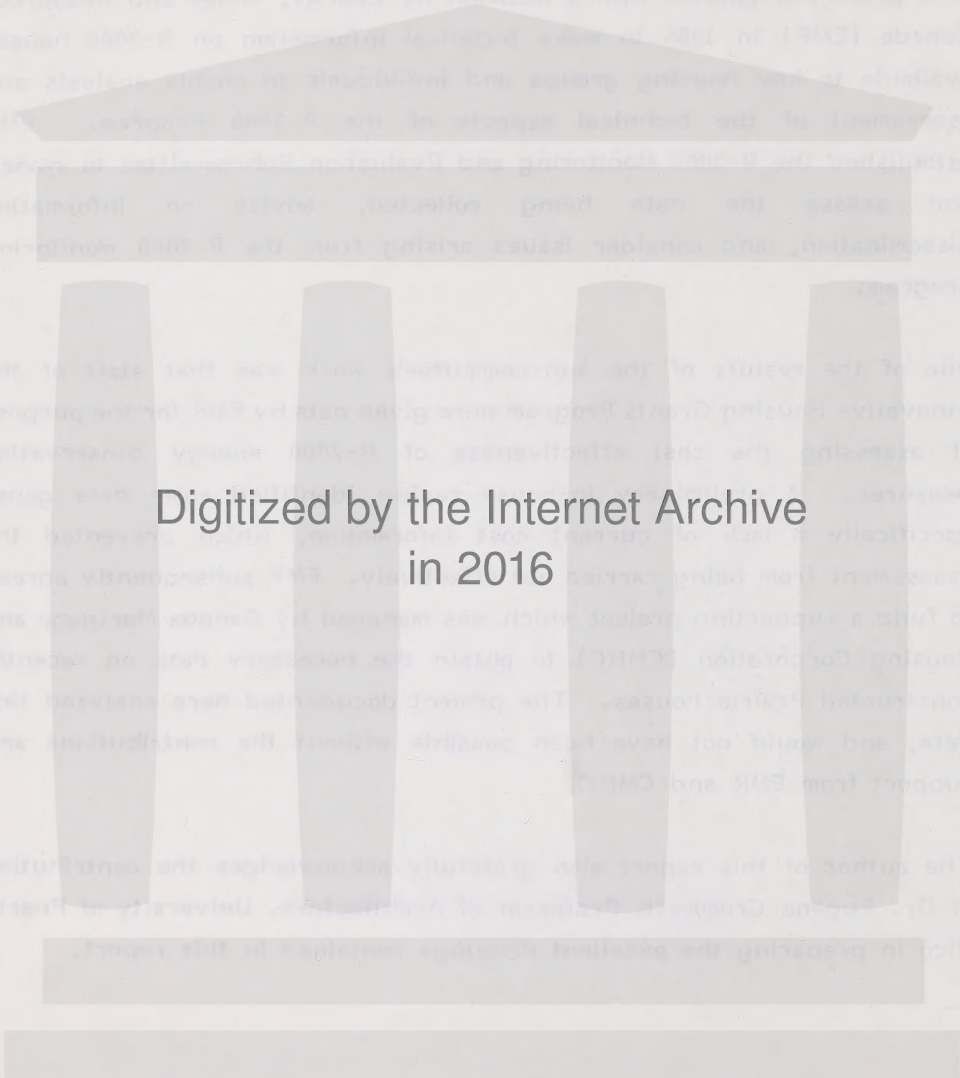
This project originated with a decision by Energy, Mines and Resources Canada (EMR) in 1985 to make technical information on R-2000 houses available to key housing groups and individuals to enable analysis and assessment of the technical aspects of the R-2000 Program. EMR established the R-2000 Monitoring and Evaluation Subcommittee to review and assess the data being collected, advise on information dissemination, and consider issues arising from the R-2000 monitoring program.

One of the results of the sub-committee's work was that staff of the Innovative Housing Grants Program were given data by EMR for the purpose of assessing the cost effectiveness of R-2000 energy conservation measures. A preliminary in-house review identified some data gaps, specifically a lack of current cost information, which prevented the assessment from being carried out effectively. EMR subsequently agreed to fund a supporting project which was managed by Canada Mortgage and Housing Corporation (CMHC) to obtain the necessary data on recently constructed Prairie houses. The project documented here analyzed this data, and would not have been possible without the contributions and support from EMR and CMHC.

The author of this report also gratefully acknowledges the contribution of Dr. Eugene Crommett, Professor of Architecture, University of Puerto Rico in preparing the excellent drawings contained in this report.



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EXECUTIVE SUMMARY

INTRODUCTION

Since 1982, when the R-2000 Program was initiated as a pilot project to promote energy efficient housing, standards and techniques under the program have evolved, and a number of builders have become more proficient in building successive R-2000 houses. The R-2000 Program has also had a significant impact on traditional construction techniques.

While earlier studies investigating the cost effectiveness of R-2000 measures have been done, they are not definitive, because:

1. the costs were incurred by builders who were still learning and adapting new techniques;

2. the costs did not reflect optimized techniques which evolved as builders built successive R-2000 units; and,

3. the costs did not reflect local variations in construction methods and energy conservation measures.

Consequently, there was a need for an updated cost effectiveness study which examined more recent data reported by builders of R-2000 units. The purpose of the project described in this report was to compile this data into a readily usable format and to analyse it in order to provide a more accurate assessment of current R-2000 techniques and incremental costs.

OBJECTIVES

The main objectives for this project were to:

1. analyse the actual costs of energy conservation measures and related building components used under the R-2000 Program;

2. determine the cost effectiveness of the energy conservation measures;

3. assess the results and describe differences in construction practices and incremental costs with respect to local conditions; and,

4. make recommendations, on a regional basis, on appropriate energy conservation techniques based on the experience with the R-2000 houses studied.

METHODS

The actual costs of R-2000 energy conservation measures and related building components were determined by examining recent costs being reported by experienced R-2000 builders in Alberta, Saskatchewan, and Manitoba on a selected sample of R-2000 houses. Energy consumption values were predicted using the HOT-2000 Energy Analysis Program. In addition, the actual R-2000 house designs investigated were optimized using the HOT-2000 computer program with the goal of minimizing incremental costs and maximizing cost effectiveness. The resultant data were tabulated, assessed and used to develop recommendations.

FINDINGS

Based on the information gathered from the Prairie builders, the point has been reached where the building envelope of an R-2000 house optimized using the HOT-2000 program is almost identical to a conventional house. Typically, to upgrade the building envelope from a conventional to an optimized R-2000 house, a builder need only provide additional care when air sealing and increase basement wall insulation to R-20. The major change in the construction of the optimized R-2000 house occurs with the mechanical system where standard gas-fired space and domestic water heating equipment is replaced with higher efficiency heating equipment and a heat recovery ventilator is installed.

The average incremental cost of the optimized R-2000 house, as a percentage of the selling price, was approximately 2.5% in each province. This incremental cost was typically $1000 to $2500 less than the incremental cost of the non-optimized actual R-2000 houses examined.

Some of the R-2000 builders reported on a number of construction innovations that resulted from integrating R-2000 concepts and techniques with standard building practices. The goal of these builders was to have the construction of the R-2000 house interfere as little as possible with their standard construction methods. Their techniques are detailed in this report.

CONCLUSIONS AND RECOMMENDATIONS

Variations in conventional construction practices in different cities precludes a common base for comparing R-2000 incremental costs on a provincial or regional basis, and results in the wide range of payback periods noted in the table below. Nevertheless, information from different sections of the report can be brought together to characterize a specific house for the purpose of choosing a

set of energy conservation upgrades that best suit a particular budget or marketplace.

The study concluded that, where higher efficiency natural gas heating appliances are used, simple payback periods shown in the following table can be achieved:

COMPONENTS	PAYBACK PERIOD		
	Alberta (P=$2.70/GJ)	Saskatchewan (P=$3.40/GJ)	Manitoba (P=$5.30/GJ)
R-20 basement walls	4 - 10 yrs	2 - 9 yrs	2 - 10 yrs
Air sealing and HRV (medium-large house)	6 - 10 yrs	3 - 7 yrs	3 - 4 yrs
Entire R2000 package	15 - 25+ yrs	5 - 20 yrs	4 - 13 yrs

P = Natural gas price

A simple payback period of less than 5 years is considered acceptable while a period greater than 10 years is not considered acceptable. Acceptance of payback periods between 5 and 10 years depends on the individual.

Several typical R-2000 components such as exterior walls greater the R-20, attic insulation greater than R-50 and higher performance windows were shown not to be cost effective upgrades and should only be considered in order to meet the R-2000 energy target after cost effective measures have been incorporated into the R-2000 design.

1.0 INTRODUCTION

1.1 The R-2000 Program

The R-2000 Program was initiated as a pilot project in 1982. Builders constructed 300 houses and established the foundation for the main phase of the program which began in the spring of 1986. This five-year phase of the program maintains the fundamental goal of having the R-2000 concepts and practices widely accepted by the residential construction industry.

The R-2000 program, once jointly administered by Energy, Mines and Resources Canada (EMR) and the Canadian Home Builders' Association (CHBA), is now funded by EMR and administered by the CHBA. Funding for the main phase totals $50,000,000 which finances program administration, industry training, construction verification and the marketing required to make the project a success. In addition, until 1988, builders were provided with funding to assist them in offsetting training, supervision and administration costs. Builder incentives ranged from $7,500 in the first year to $500 in the final year of the incentive stage. Although only a fraction of the goal of constructing 20,000 R-2000 units has formally been achieved, it is evident that the program has had a significant impact on traditional construction practices.

Although the management of the program has changed, the technical requirements have remained constant over the life of the program with the exception of minor modifications to reflect new technical and administrative innovations. The most significant change is one which allows builders to use prescriptive standards instead of a detailed design analysis to determine the heat loss of their R-2000 home. Few additional changes are anticipated for the remainder of the program. A summary of current R-2000 Technical Requirements is given in Appendix A.

1.2 R-2000 Cost Effectiveness

Previous work has been conducted on establishing the incremental cost of R-2000 homes and the construction techniques used in achieving the R-2000 energy target. The following work has been completed:

1. *Incremental Construction Cost Analysis of R-2000 Homes Built in 1983.* M. Lubun and Assoc., 1986.

2. *Cost Effectiveness Study of R-2000 Homes Built in 1983.* M. Lubun and Associates, 1986.

3. *Incremental Cost Analysis of R-2000 Homes.* Bureau of Management Consultants (BMC), 1986.

4. *Incremental Cost Analysis of Energy Conservation Systems.* Prepared by Unies Ltd. for Energy, Mines, and Resources, Canada. June, 1988.

These studies are not definitive, however, because:

1. the costs were incurred by builders who were still learning and adapting new techniques;

2. the costs did not reflect optimized techniques which evolved as builders built successive R-2000 units; and,

3. the costs did not reflect local variations in construction methods and energy conservation measures.

Consequently, there was a need for an updated cost effectiveness study which examined more recent data on builders of R-2000 units. Under a previous Canada Mortgage and Housing Corporation (CMHC) project, data was gathered by Howell-Mayhew Engineering during the winter of 1988 on the actual costs incurred, and techniques used, in building R-2000 houses in the Prairie Region. The purpose of the project described in this report was to compile the CMHC data into a readily usable format and to analyse it in order to provide a more accurate assessment of current R-2000 techniques and incremental costs.

1.3 Objectives

The main objectives for this project were to:

1. analyse the actual costs of energy conservation measures and related building components used under the R-2000 Program by examining recent costs being reported by experienced R-2000 builders in Alberta, Saskatchewan, and Manitoba on a selected sample of R-2000 houses;

2. determine the cost effectiveness of the energy conservation measures used in the selected houses using energy consumption values predicted by the HOT-2000 Energy Analysis Program;

3. assess the results and describe differences in construction practices and incremental costs with respect to local conditions; and,

4. make recommendations, on a regional basis, on appropriate energy conservation techniques based on the experience with the R-2000 houses studied.

For comparison purposes, houses discussed in this report have been categorized in the following manner.

Conventional	- a modified version of the Actual R-2000 house built to the conventional construction specifications of the particular builder.
Actual R-2000	- an R-2000 house recently constructed using techniques and materials representative of other R-2000 houses built in a particular area.
Optimized	- a modified version of the Actual R-2000 house R-2000 that would minimize costs and result in a yearly energy budget (calculated using the HOT-2000 program) as close as possible to the maximum allowed for R-2000 houses.
Prescriptive Standards R-2000	- an R-2000 house constructed according to criteria specified by the Canadian Home Builders' Association.

2.0 CONTRACTOR AND HOUSE INFORMATION

2.1 Selection Process

The R-2000 builders and houses used in this study were selected by the provincial R-2000 coordinators from Energy, Mines and Resources, Canada (EMR) and the Canadian Home Builders' Association (CHBA).

2.2 Builder and House Distribution

The location, distribution and number of builders and houses included in this study are as follows:

Location		Number of Builders	R-2000 Houses
Northern Alberta:	o Edmonton	4	7
	o Red Deer	1	2
Southern Alberta	o Calgary	2	4
Saskatchewan:	o Saskatoon	2	4
	o Regina	2	4
Manitoba:	o Winnipeg	4	7
	TOTALS	15	28

2.3 Contractor Profile

Initially, only experienced R-2000 builders who had constructed at least five R-2000 houses since December, 1985 were to be chosen to participate in the study. In the Prairie Region, however, flexibility was required in order to find a sufficient number of builders and to include the largest builder with R-2000 experience in each center. A profile of each of the builders selected is presented in Table 1.

Note: The *Builder Number* in Table 1 will be used to reference each R2000 builder throughout this report.

2.4 Actual R-2000 Information

Most builders provided information on two of their Actual R-2000 houses. The houses selected incorporated construction techniques and materials which were representative of other R-2000 homes being built in the contractor's region. A profile of each of these houses is given in Table 2.

Note: The *Builder/House Number* in Table 2 will be used to reference each R-2000 house throughout this report.

Table 1: CONTRACTOR PROFILE

Builder Number	City	Prov	Years in Business	# Houses/ Year	Total # R2000 Houses Since 1985	Total # R2000 Houses	Comments
1.	Edmonton	Alta	12	120	1	1	This builder did not meet initial project criteria but was the largest builder with R-2000 experience. Interview conducted with owner who has a construction background.
2.	Edmonton	Alta	3	25-30	5	5	Experienced R-2000 builder. Interview conducted with the owner who was educated as a civil engineering technologist and had experience in estimating, planning and project management.
3.	Edmonton	Alta	14	6	7	14	Most innovative and prolific R-2000 builder in Edmonton. Interview conducted with owner who has an engineering background.
4.	Edmonton	Alta	2	10	4	4	A quality builder of innovative R-2000 homes. Interview conducted with owner who has 15 years building experience and 2.5 years engineering.
5.	Red Deer	Alta	8	3	8	11	Most knowledgeable R-2000 builder in province and the most committed to the program. Interview conducted with owner who was trained as as a civil engineer and worked 17 years commercial.
6.	Calgary	Alta	10	57	5	8	Most prolific R-2000 builder and largest builder with R-2000 experience in Calgary. Interview conducted with owner who is a civil engineer by profession.
7.	Calgary	Alta	9	3	3	4	Most innovative and knowledgable R-2000 builder in Calgary area. Interview was conducted with owner who is a mechanical engineer by profession.
8.	Regina	Sask	14	10	4	7	Interview conducted with owner who has a background in commercial construction.
9.	Regina	Sask	16	30	11	11	Largest R-2000 builder in Regina. Interview conducted with owner who has a background in construction.
10.	Saskatoon	Sask	16	110	3	6	Largest builder in Saskatoon. Interview conducted with general manager, construction supervisor and estimator.
11.	Saskatoon	Sask	5	40	22	24	Most prolific R-2000 builder in Saskatoon. Interview conducted with owner who was a banker 12 years and with builder #10 for 3 years in sales marketing and management.
12.	Winnipeg	Man	7	21	4	6	Interview conducted with owner who has background in construction.
13.	Winnipeg	Man	35	200	13	.	Second largest builder in Winnipeg. Interview conducted with general manager, construction supervisor and estimator.
14.	Winnipeg	Man	11	350	18	30	Largest builder in Winnipeg and most prolific R-2000 builder. Interview conducted with general manager.
15.	Winnipeg	Man	10	45	3	3	Moderate sized builder of custom homes. Interview conducted with owner who has a construction background.

Table 2: R-2000 HOUSE INFORMATION

Builder/ House Number	Finish Date	Type	Exterior Finish	Air Test	Developed[1] Floor Area		Basement Floor Area		Envelope Surface Area		Total Volume	
				(ACH)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^2)	(m^2)	(ft^3)	(m^3)
Edmonton												
1.	JA 88	2-storey	vinyl siding	1.30	2250	209.1	1345	125.0	6488	603.0	31350	887.9
2a.	MR 87	2-storey	stucco	1.34	2452	227.9	1385	128.7	6410	595.7	29975	848.9
2b.	MR 88	2-storey	vinyl siding	1.20	2060	191.4	1041	96.7	6211	577.2	25162	712.6
3a.	MA 86	Bungalow	vinyl siding	1.41	1201	111.6	1194	111.0	4904	455.8	18641	527.9
3b.	NO 87	2-storey	vinyl siding	1.38	2159	200.7	1342	124.7	6117	568.5	28810	815.9
4a.	MA 88	2-storey	stucco	.83	1700	158.0	900	83.6	4487	417.0	19846	562.1
4b.	MA 88	2-storey	brick	.65	2400	223.0	1500	139.4	6784	630.5	34111	966.0
Red Deer												
5a.	DE 87	2-storey	vinyl siding	.49	1563	145.3	681	63.3	4853	451.0	19979	565.8
5b.	SE 87	bilevel	vinyl siding	.77	2171	201.8	0	0	4353	404.6	17063	483.2
Calgary												
6a.	OC 87	2-storey	vinyl siding	1.36	2402	223.2	1542	143.3	7257	674.4	32086	908.7
6b.	NO 87	2-storey	vinyl siding	1.48	1865	173.3	1168	108.6	5786	537.7	25994	736.2
7a.	NO 85	duplex	stucco	1.10	840	78.1	840	78.1	2829	262.9	12256	347.1
7b.	JU 87	bilevel	alum. siding	.80	2316	215.2	0	0	4425	411.2	18264	517.2
Regina												
8a.	MR 87	bungalow	stucco	1.23	1720	159.9	1720	159.9	6433	597.9	26271	744.0
8b.	OC 87	2-storey	stucco	n/a	2800	260.2	1400	130.1	6318	587.2	30970	877.1
9a.	AU 86	split	stucco	1.41	1660	154.3	1040	96.7	6572	476.1	22492	637.0
9b.	MA 87	bungalow	stucco	1.07	1850	171.9	1850	171.9	5122	610.8	27401	776.0
Saskatoon												
10a.	AL 86	split	stucco	1.43	1050	97.6	1001	93.0	4356	404.8	15967	452.2
10b.	DE 86	2-storey	hardboard	1.45	2475	230.0	1148	106.7	6850	592.6	32269	913.9
11a.	FE 87	bungalow	vinyl siding	1.18	1108	103.0	1108	103.0	4185	388.9	19461	551.1
11b.	NO 87	split	vinyl siding	n/a	1888	175.5	664	61.7	5451	506.6	22443	635.6
Winnipeg												
12a.	AU 87	bungalow	stucco	.40	1343	124.8	1343	124.8	5515	512.5	23076	653.5
12b.	JL 87	bungalow	stucco	.64	1505	139.9	1505	139.9	4654	432.5	19584	554.6
13.	FE 88	2-storey	stucco	n/a	2373	220.5	1029	95.6	5940	552.0	24692	699.3
14a.	NO 87	split	stucco	.65	1700	158.0	500	46.5	4723	438.9	17684	500.8
14b.	FE 88	2-storey	stucco	n/a	1775	165.0	800	74.3	4856	451.3	18980	537.5
15a.	AU 87	2-storey	stucco	1.37	1808	168.0	1069	99.3	6060	563.2	21781	616.9
15b.	DE 87	bungalow	stucco	.67	1330	123.6	1330	123.6	4908	456.1	18858	534.1

1. Developed Floor Area refers to the finished floor area and does not include the basement.

2.5 Data Collection

Data was collected for Conventional, Actual R-2000, and Optimized R-2000 houses during interviews conducted at each builder's office. Prescriptive Standards R-2000 house data was compiled separately by Howell-Mayhew Engineering.

During the interview, each builder provided technical and cost information on the construction of specific R-2000 houses and on the construction of the same home built to his conventional standard. Then, using the HOT-2000 computer program, the Actual R-2000 house design was optimized by making changes that were practical and cost effective for the builder.

The data has been organized into a number of tables that are presented in this report. The tables summarize each builder's approach to upgrading different components of the building envelope and the mechanical system.

A list the of abbreviations used in these tables and metric conversions are presented on the following pages.

LIST OF ABBREVIATIONS USED IN THE TABLES

Building Envelope

AB	- air barrier
VB	- vapour barrier
blocks	- wood of rigid insulation blocks installed between floor joist
cast	- cast-in-place floor joist
Cartier Bd.	- Cartier Board: foil-backed, rigid fiberglass insulation
dbl	- doubled glazed
Glascd	- Glasclad: rigid fiberglass insulation
I	- insulation
low E	- low emissivity glazing
mil	- thickness of polyethylene
P	- polyethylene
PWF	- preserved wood foundation
recess	- recessed rim joist
R12-2'below	- R-12 batt insulation to 2 feet below grade
R7.5-3ft	- 3 foot perimeter strip of R-7.5 insulation
strap	- interior strapped wall
Styro	- Styrofoam: extruded polystyrene insulation
T	- type
Ther	- Thermax: rigid polyisocyanurate insulation
tri	- triple glazing
Tyvek	- spun-woven, polyolefin housewrap
wood/BM	- framing member and bituthene membrane (see Figure 5 and 6)

Mechanical System

elec	- electric
EQN	- equation used to calculate complex billing rate
fans	- standard bathroom and kitchen fans
G/E	- represents a change from natural gas to electricity
hi (air sealing)	- building envelope sealed to R-2000 standards
med (air sealing)	- polyethylene well sealed but not envelope penetrations
std	- standard heating equipment
hi (furnace)	- high efficiency gas-fired furnace ie >90% efficient
mid (furnace)	- medium efficiency gas-fired furnace ie >80% efficient
ht pmp	- ground-to-air heat pump
mid (water heater)	- induced draft or sealed combustion water heater
HRV	- heat recovery ventilator
hi (HRV)	- high efficiency HRV ie >75% efficient
mid (HRV)	- medium efficiency HRV ie >60% efficient

METRIC CONVERSIONS

Conversion	to get	multiply	by
length	mm	inches	25.4
	m	feet	0.3048
area	m^2	ft^2	0.0929
		yd^2	0.836127
volume	m^3	ft^3	0.028317
		yd^3	0.764555
flow	L/s	cfm	0.471947

Polyethylene Conversions

4 mil equals .10 mm
6 mil equals .15 mm

Insulation Unit Conversions

Imperial	*Metric*	
R 7.5	RSI	1.32
R 10	RSI	1.76
R 12	RSI	2.11
R 20	RSI	3.52
R 25	RSI	4.40
R 27.5	RSI	4.84
R 32	RSI	5.64
R 40	RSI	7.04
R 50	RSI	8.81
R 60	RSI	10.57

Nominal Lumber Conversions

Imperial	*Metric*
2 X 2 in.	38 X 38 mm
2 X 3 in.	38 X 64 mm
2 X 4 in.	38 X 89 mm
2 X 6 in.	38 X 140 mm
2 X 8 in.	38 X 190 mm
2 X 10 in.	38 X 235 mm
2 X 12 in.	38 X 286 mm

3.0 ENERGY CONSERVATION MEASURES

Section 3.0 presents all the construction specifications and energy consumption estimates for the Conventional, Actual R-2000 and Prescriptive Standards R-2000 houses. Information on the physical makeup of each house is detailed in this section.

3.1 Conventional Construction Practices

The builders' information on their conventional practices, along with HOT-2000 energy consumption predictions, provided the specifications for the Conventional house against which the Actual R-2000 house was compared. This information is presented in Tables 3a and 3b.

Comments

1. Slab/Foundation

All builders use concrete foundations and slabs with the exception of Alberta Builder #5 who constructs all of his houses on preserved wood foundations (PWF). The use of polyethylene under the slab varied from usage by all of the builders in Alberta to no usage at all in Manitoba.

2. Basement Walls

Basement walls in Alberta and Manitoba are typically insulated full height with R-12 batt insulation. In Saskatchewan, however, one Regina builder does not insulate his basement walls while the other installs R-12 to two feet below grade. Both Saskatoon builders install full height R-20 basement walls in all of their conventional houses.

3. Rim Joist Area

Three of the four contractors interviewed in northern Alberta, Saskatchewan, and Manitoba have the cribber install the floor joist system which is subsequently cast-in-place. The fourth contractor in each of these areas has the framer install the joist after the foundation is poured. In Calgary, cast-in-place foundations are not used because most foundation contractors do not offer this option.

The rim joist area is usually insulated with R-20, and in all houses a polyethylene vapour retarder is installed to the inside. Only two builders install a continuous air barrier around the rim joist of their conventional houses. Builder #4, from Edmonton, wraps this area with a building wrap made of a spun-bonded, polyolefin called Tyvek. This

technique is detailed in Section 8.0. Builder #11, from Saskatoon, recesses the rim joist area and installs a foil-backed, rigid fiberglass product called Cartier Board.

4. Cantilevers

All builders install R-32 in the cantilever joist space.

5. Exterior Walls

Insulating the exterior walls with R-20 batts is standard in all regions except Saskatoon where the largest builder installs an exterior rigid insulation on all his conventional houses to achieve R-28. Three-quarters of the builders are using 6 mil polyethylene and all of the builders are sealing the polyethylene creating a combined air/vapour barrier.

6. Attic/Roof

Attics are typically insulated to R-40 with blown insulation.

7. Windows

Double glazing is standard in all conventional houses in Alberta and Regina while triple glazing is standard in Saskatoon and Manitoba.

8. Exterior Doors

All builders install insulated steel doors in their conventional houses.

9. Air Sealing

From the main floor subfloor up, all conventional houses are well sealed. From the subfloor down, however, including cantilevers, the rim joist area and the basement, no special attention is paid to air sealing, except by the two builders noted in Comment #3.

10. Fuel

Natural gas was the builders' fuel of choice for all conventional houses. Builder #12, in a rural setting near Winnipeg, uses electric appliances because of the high cost of installing a natural gas line.

11. Space Heating

Typically, standard heating appliances are installed. Three custom builders in Edmonton, however, now install medium efficiency furnaces in all their houses because of customer demand. The short payback period of this furnace makes it an attractive investment.

12. Water Heating

Standard water heating equipment is installed in all areas.

13. Ventilation Equipment

Although standard kitchen and bathroom fans are typically installed in houses in Alberta and Manitoba, three of the four Saskatchewan builders install a central exhaust system in all of their conventional houses. In this way, the house is ducted to readily accept a more sophisticated ventilation system, such as a heat recovery ventilator.

3.2 Actual R-2000 Construction Practices

The information provided by the builders on upgrading from conventional to R-2000 specifications is presented in Tables 4a and 4b. These tables have been grouped with Tables 3a and 3b to allow comparisons to be made between the Conventional and Actual R-2000 house construction specifications and practices.

Comments

1. Slab/Foundation

Perimeter insulation under the floor slab was installed in approximately one-third of the houses with builders insulating a two to four foot strip with one to two inches (R-5 to R-10) of extruded polystyrene (Styrofoam) insulation. House #12b had a three foot strip of two inch expanded polystyrene (beadboard) insulation. Two of the Manitoba builders who had not used polyethylene under the slab on their Conventional houses used it on their Actual R-2000 houses.

Exterior foundation insulation from the subfloor to the footing was used by two Winnipeg builders. Builder #12 installed one inch of Styrofoam (R-5) to achieve an overall basement wall insulation value of R-25 in House #12b. Builder #15 installed two inches of Baseclad (a rigid fiberglass insulation) to the exterior foundation of each of his Actual R-2000 houses to achieve an R-28 basement wall in House #15a and R-20 in House #15b.

One Alberta builder continued his exterior wall insulation over the foundation wall to grade and achieved an R-25 above grade basement wall.

2. Basement Walls

Basement walls were upgraded to a minimum R-20 in all houses.

3. Rim Joist

Builders using cast-in-place joisting practices found that they have had to change framing techniques in order to achieve a continuous air barrier from the main floor wall, across the rim joist area, to the basement wall. Many found this change too disruptive to the construction process and devised innovative techniques for achieving a continuous air barrier while maintaining conventional cast-in-place construction practices. These techniques are detailed in Section 8.0.

4. Cantilevers - No insulation changes.

5. Exterior Walls

Upgrading was carried out on the exterior walls of 16 of the Actual R-2000 homes. The type of upgrade and the number of houses involved were as follows:

a) Exterior insulation - 11: Styrofoam - 7
Glasclad - 2
Thermax - 2
b) Interior strapping - 2
c) Expanded wall (2x8) - 2
d) Double wall - 1

The standard specifications of the two homes constructed by Builder #10 in Saskatoon included exterior Styrofoam insulation. The 10 remaining homes that were not upgraded remained at R-20.

6. Attic/Roof

Attic insulation was increased in 18 of the 28 Actual R-2000 houses. The design R-values and the number of houses receiving the upgrade were as follows:

a) R-60: 4
b) R-55: 2
c) R-50: 10
d) R-45: 2

7. Windows

Windows were upgraded in 13 homes. The type of upgrade and the number of houses involved are as follows:

a) Triple glazing - 10.5 (House #7b had one half triple and
b) Low-E - 0.5 one half low-E glazing)
c) Heat Mirror - 2

8. Exterior Doors - No changes.

9. Air Sealing

In order to achieve the R-2000 Program air tightness standard, builders paid special attention to building envelope penetrations, cantilevers and the rim joist area.

10. Fuel

Natural gas was a less expensive source of energy than electricity in all three provinces. Some of the builders switched from gas to electricity in their Actual R-2000 houses believing that the savings incurred by not having to invest in high efficiency gas-fired heating equipment, combined with the reduced R-2000 heat load, would result in overall savings. As the economic analysis in Section 7.0 revealed, this was not the case.

11. Space Heating

Space heating systems were changed in 21 of the Actual R-2000 houses. The changes included:

a) High efficiency gas - 6
b) Medium efficiency gas - 9
c) Electric furnace - 5
d) Heat pump - 1

12. Water Heating

The water heater was upgraded in 26 homes and included:

a) Medium efficiency gas - 18
b) Electric - 8

The other two used electric water tanks.

13. Ventilation Equipment

All ventilation systems were upgraded and included:

a) High efficiency HRV - 5
b) Medium efficiency HRV - 23

Table 3a: BUILDER'S CONVENTIONAL SPECIFICATIONS (* - Denotes not installed)

		Northern Alberta Edmonton				Southern Alberta Red Deer	Calgary	
Builder Number		1	2	3	4	5	6	7
Building Envelope								
Slab/Foundation	I	*	*	*	*	*	*	*
	P	6 mil	6 mil	4 mil	6 mil	6 mil	4 mil	6 mil
Basement Walls	I	R 12	R 12	R 12	R 12	R 24 (PWF)	R 12	R 12
	P	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil
Rim Joist	T	cast	cast	cast	framed	framed	framed	framed
	I	R 12	R 20	R 20	R 20	R 20	R 20	R 12
	AB	*	*	*	Tyvek	*	*	*
	VB	poly	poly	poly	poly	poly	poly	poly
Cantilevers	I	R 32	R 32	R 32	R 32	R 32	R 32	R 32
Exterior Walls	I	R 20	R 20	R 20	R 20	R 20	R 20	R 20
	P	4 mil	4 mil	6 mil	6 mil	4 mil	4 mil	6 mil
Attic/Roof	I	R 40	R 40	R 40	R 40	R 40	R 34	R 34
	P	4 mil	4 mil	6 mil	6 mil	4 mil	4mil	6 mil
Windows		dbl	dbl	dbl	dbl	dbl	dbl	dbl
Exterior Doors		R 14	R 14	R 14	R 14	R 14	R 14	R 14
Air Sealing		med	med	med	hi	med	med	med
Mechanical System								
Fuel		gas	gas	gas	gas	gas	gas	gas
Space Heating		std	mid	mid	mid	std	std	std
Water Heating		std	std	std	std	std	std	std
Ventilation Equipment		fans	fans	fans	central fan	fans	fans	fans

Table 4a: BUILDER'S UPGRADE TO ACTUAL R-2000 SPECIFICATIONS (* - Denotes no change from conventional specifications)

Builder/House Number		1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Building Envelope														
Slab/Foundation	I	*	R10-3ft	*	R5-3ft	R5-2ft	*	R10-4ft	*	*	*	*	R7.5-3ft	R7.5-3ft
	P	*	*	*	*	*	*	*	*	*	*	*	*	*
Basement Walls	I	R 20	R 20	R 20	R 20	R 20	R 20	R 20	*	*	R 20	R 20	R20/R25	R20/R25
	P	6 mil	*	*	*	*	*	*	*	*	*	*	*	*
Rim Joist	T	recess	recess	recess	recess	*	*	*	*	*	*	*	recess	recess
	I	R 20	*	*	R 23	R 27	*	*	*	*	*	*	R 20	R 20
	AB	poly	poly	poly	poly	wood/BM	*	*	Tyvek	Tyvek	blocks	blocks	poly	poly
	VB	*	*	*	*	*	*	*	*	*	blocks	blocks	*	*
Cantilevers	I	*	*	*	*	*	*	*	*	*	*	*	*	*
Exterior Walls	I	*	R 27.5	R 25	R 28	R 27	R 24	R 24	*	*	R 26	R 26	R 27	R 27
	T	*	Styro	Styro	strap	Styro	2x8	2x8	*	*	Therm	Therm	Styro	Styro
	P	6 mil	*	*	*	*	*	*	*	*	*	*	*	*
Attic/Roof	I	*	R 60	R 60	R 50	R 50	R 50	R 50	*	R 60	R 45	R 50	R 50	R 50
	P	6 mil	*	*	*	*	*	*	*	*	*	*	*	*
Windows		Ht Mr	tri-N	*	tri	tri	tri	tri	tri	tri	*	*	*	tri/lowE
Exterior Doors		*	*	*	*	*	*	*	*	*	*	*	*	*
Air Sealing		hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi	hi
Mechanical System														
Fuel		*	*	*	*	*	*	*	*	*	*	*	elec	*
Space Heating		hi	*	*	*	*	*	*	mid	mid	mid	mid	elec	mid
Water Heating		mid	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid
Ventilation Equipment		mid	mid	hi	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid

Table 3b: BUILDER'S CONVENTIONAL SPECIFICATIONS (* - Denotes not installed)

		Saskatchewan Regina		Saskatoon		Manitoba Winnipeg			
Builder Number		8	9	10	11	12	13	14	15
Building Envelope									
Slab/Foundation	I	*	*	*	*	*	*	*	*
	P	6 mil	*	6 mil	6 mil	*	*	*	*
Basement Walls	I	*	R 12-2' below	R 20	R 20	R 12	R 10	R 12	R 12
	P	*	*	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil
Rim Joist	T	cast	cast	cast	framed	framed	cast	cast	cast
	I	R 20	R 12	R 20	R 40	R 20	R 20	R 20	R 20
	AB	*	*	*	Cartier Bd.	*	*	*	*
	VB	poly	poly	poly	poly	poly	poly	poly	poly
Cantilevers	I	R 32	R 32	R 32	R 32	R 32	R 32	R 32	R 32
Exterior Walls	I	R 20	R 20	R 28	R 20	R 20	R 20	R 20	R 20
	P	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil
Attic/Roof	I	R 40	R 40	R 40	R 40	R 40	R 40	R 40	R 40
	P	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil	6 mil
Windows		dbl	dbl	tri	tri	tri	tri	tri	tri
Exterior Doors		R 14	R 14	R 14	R 14	R 14	R 14	R 14	R 14
Air Sealing		med	med	med	med	hi	med	med	med
Mechanical System									
Fuel		gas	gas	gas	gas	elec	gas	gas	gas
Space Heating		std	std	std	std	elec	std	std	std
Water Heating		std	std	std	std	elec	std	std	std
Ventilation Equipment		central fan	fans	central fan	central fan	fans	fans	fans	fans

Table 4b: BUILDER'S UPGRADE TO ACTUAL R-2000 SPECIFICATIONS (* - Denotes no change from conventional specifications)

Builder/House Number		8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
Building Envelope																
Slab/Foundation	I	*	*	*	*	*	*	R7.5-3ft	*	*	R8-3ft	*	*	*	R10-3ft	*
	P	*	*	*	*	*	*	*	*	*	6 mil	*	*	*	6 mil	6 mil
Basement Walls	I	R 20	R 20	R 20	R 20	*	*	*	*	*	R 25	R 20	R 20	R 20	R 28	R 20
	P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Rim Joist	T	recess	recess	recess	recess	*	*	*	*	*	*	*	*	*	*	*
	I	R 40	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	AB	poly	poly	blocks	blocks	*	*	*	*	*	*	*	*	*	blocks	blocks
	VB	*	*	blocks	blocks	*	*	*	*	*	*	*	*	*	blocks	blocks
Cantilevers	I	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Exterior Walls	I	R 40	*	*	*	*	*	R 27.5	R 27.5	*	R 28	*	*	*	R 28	R 28
	T	dbl wl	*	*	*	*	*	Styro	Styro	*	strap	*	*	*	Glascd	Glascd
	P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Attic/Roof	I	R 60	*	*	*	*	*	R 55	R 55	*	R 50	*	*	R 45	R 50	R 50
	P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Windows		*	tri	tri	tri	*	*	*	*	*	*	*	*	*	*	Ht Mr
Exterior Doors		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Air Sealing		hi	hi	hi	hi	*	*	hi	hi	*	hi	hi	hi	hi	hi	hi
Mechanical System																
Fuel		*	*	*	*	*	*	*	*	*	*	el/gas	elec	elec	elec	elec
Space Heating		mid	hi	hi	hi	hi	hi	mid	mid	ht pmp	elec	mid	elec	elec	elec	elec
Water Heating		mid	mid	mid	mid	mid	mid	elec	elec	elec	elec	elec	elec	elec	elec	mid
Ventilation Equipment		mid	mid	mid	mid	mid	mid	mid	mid	mid	mid	hi	mid	hi	hi	hi

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3.3 Optimized R-2000 Specifications

As a design exercise to provide additional data for this project, the builders optimized their Actual R-2000 house designs using the HOT-2000 program. The objective was to bring the estimated energy consumption as close as possible to the R-2000 energy target while minimizing construction costs. The Optimized R-2000 house was never specified lower than a builder's Conventional house. The Optimized R-2000 house information is presented in Tables 5a and 5b.

Comments

1. Slab/Foundation

Perimeter insulation under the floor slab was removed from all Actual R-2000 house designs where it had initially been installed. Builders found this upgrade expensive from a material and supervision standpoint.

Exterior foundation insulation was dropped as an upgrade in all houses because it was too expensive.

2. Basement Walls - No changes.

3. Rim Joist

Optimization in this area came in the form of air sealing techniques. These are discussed in detail in Section 8.0.

4. Cantilevers - No changes.

5. Exterior Walls

Fifteen of the 16 houses with upgraded exterior walls were reduced to R-20. Builders found that the combination of triple glazing and a high efficiency HRV allowed them to eliminate the high cost of the exterior insulation upgrade, maintain their conventional construction practices and still meet the R-2000 energy target.

6. Attic/Roof

Only six of the Optimized R-2000 homes required insulation levels above R-40. The levels ranged from R-42 to R-55 and were chosen to allow the house to just meet the R-2000 energy target.

7. Windows

In all Alberta cities and in Regina, where double glazing was standard on the Conventional houses, builders found that they could usually meet the R-2000 energy target without

triple glazing. Only two houses in these regions required triple glazing. In Saskatoon and Winnipeg triple glazing is standard and was not changed in the Optimized R-2000 homes.

Builder #15, who chose electric heating for his Actual R-2000 House #15a, required an upgraded exterior wall to meet the R-2000 energy target.

8. Exterior Doors - No changes.

9. Air Sealing - No changes.

10. Fuel - No changes.

11. Space Heating

All six high efficiency furnaces were replaced with medium efficiency units. No other changes were made.

12. Water Heating

Builder #11 switched from electric to medium efficiency gas-fired water heaters. This increased the R-2000 energy target by 15,800 MJ allowing him to realize large cost savings by reducing envelope insulation levels.

13. Ventilation Equipment

In Alberta, 10 of the 12 Actual R-2000 houses equipped with medium efficiency HRV's were upgraded to high efficiency units in the Optimized R-2000 houses. In the other centers, only three of the 11 medium efficiency HRV's were upgraded. In these centers, higher building envelope R-values are standard practice.

3.4 Prescriptive Standards Specifications

The prescriptive standards set out by each provincial Home Builders' Association were used to determine the specifications of the Prescriptive Standards R-2000 house. These standards allow a certified R-2000 builder to enroll and construct a certified R-2000 house without having a certified plan evaluator conduct a detailed plan evaluation and HOT-2000 computer analysis. The Prescriptive Standards R-2000 house specifications are displayed in Tables 6a and 6b. The terminology for each component differs somewhat from province to province and this is reflected in the tables. The different terms are explained in the *List of Abbreviations* on page 8. The prescriptive standards as supplied by the provincial Home Builders' Association are included in Appendix B.

Table 5a: CHANGES TO OPTIMIZE ACTUAL R-2000 SPECIFICATIONS (* - Denotes no change from R-2000 specifications)

		Northern Alberta Edmonton							Southern Alberta Red Deer		Calgary			
Builder/House Number		1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Building Envelope														
Slab/Foundation	I	*	R 0	*	R 0	R 0	*	R 0	*	3ft-R7.5	*	*	R 0	R 0
	P	*	*	*	*	*	*	*	*	*	*	*	*	*
Basement Walls	I	*	*	*	*	*	*	*	*	*	*	*	R 20	R 20
	P	*	*	*	*	*	*	*	*	*	*	*	*	*
Rim Joist	I	*	*	*	*	*	*	*	*	*	*	*	*	*
	I	*	*	*	R 20	R 20	*	*	*	*	*	*	*	*
Cantilevers	I	*	*	*	*	*	*	*	*	*	*	*	*	*
Exterior Walls	I	*	R 20	R 20	R 20	R 20	R 20	R 20	*	*	R 20	R 20	R 20	R 20
	P	*	*	*	*	*	*	*	*	*	*	*	*	*
Attic/Roof	I	*	R 40	R 42	R 57	*	*	*	*	*	R 40	R 40	R 40	R 40
	P	*	*	*	*	*	*	*	*	*	*	*	*	*
Windows		tri	dbl-N	tri	dbl	dbl	*	*	dbl	dbl	*	*	*	dbl
Mechanical System														
Fuel		*	*	*	*	*	*	*	*	*	*	*	*	*
Space Heating		mid	*	*	*	*	*	*	*	*	*	*	*	*
Water Heating		*	*	*	*	*	*	*	*	*	*	*	*	*
Ventilation Equipment		hi	hi	*	hi	hi	hi	hi	*	hi	hi	hi	*	hi

Table 6a: R-2000 "PRESCRIPTIVE STANDARDS" (* - Denotes no change from conventional specifications)

	Northern Alberta Edmonton							Southern Alberta Red Deer		Calgary			
Builder/House Number	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Building Envelope													
Slab insulation	*	*	*	*	3ft-R7.5	*	*	3ft-R7.5	3ft-R7.5	*	*	*	*
Basement walls	R 20	R 20	R 20	R 20	R 20	R 20	R 20	*	*	R 28	R 20	R 20	R 20
Main walls	*	*	*	*	*	*	*	*	*	*	*	*	*
Ceiling	*	*	R 50	R 50	*	R 50	*	*	*	R 40	R 50	R 40	R 40
Windows	tri	tri	tri	tri	tri	*	tri	*	*	*	*	*	*
Mechanical System													
Space heater	>90%	>90%	*	*	*	>90%	>90%	>80%	>80%	>80%	>80%	>80%	>80%
Water heater	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid	mid
Ventilation Equipment	>75%	>75%	>75%	>75%	>75%	>75%	>75%	>75%	>75%	>75%	>75%	>60%	>75%

Table 5b: CHANGES TO OPTIMIZE ACTUAL R-2000 SPECIFICATIONS (* - Denotes no change from R-2000 specifications)

		Saskatchewan Regina				Saskatoon				Manitoba Winnipeg					
Builder/House Number		8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
Building Envelope																
Slab/Foundation	I	*	*	*	*	*	*	R 0	*	*	R 0	*	*	*	R 0	*
	P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Basement Walls	I	*	*	*	*	*	*	*	*	*	R 20	*	*	*	R 20	*
	P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Rim Joist	T	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	I	R 20	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cantilevers	I	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Exterior Walls	I	R 20	*	*	*	*	*	R 20	R 20	*	R 20	*	*	*	*	R 20
	P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Attic/Roof	I	R 40	R 40	R 45	*	*	*	R 40	R 50	*	R 45	*	*	R 40	R 55	R 40
	P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Windows		dbl	dbl	dbl	dbl	*	*	*	*	*	*	*	*	*	*	tri
Mechanical System																
Fuel		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Space Heating		*	mid	mid	mid	mid	mid	*	*	*	*	*	*	*	*	*
Water Heating		*	*	*	*	*	*	mid	mid	*	*	*	*	*	*	*
Ventilation Equipment		hi	hi	*	*	*	*	*	*	*	*	*	hi	*	*	*

Table 6b: R-2000 "PRESCRIPTIVE STANDARDS" (* - Denotes no change from conventional specifications)

	Saskatchewan Regina				Saskatoon				Manitoba Winnipeg						
Builder/House Number	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
Building Envelope															
Slab insulation	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Basement walls	R 20	R 20	R 20	R 20	*	*	*	*	R 20	R 20	R 20	R 20	R 20	R 20	R 20
Main walls	*	*	*	*	*	*	R 28	R 28	*	*	*	*	*	*	*
Ceiling	R 50	R 50	R 50	R 50	R 50	R 50	R 50	R 50	R 45	R 45	R 45	R 45	R 45	R 45	R 45
Windows	tri	tri	tri	tri	*	*	*	*	*	*	*	*	*	*	*
Mechanical System															
Space heater	mid	mid	mid	mid	mid	mid	mid	mid	ht pmp	elec	mid	elec	elec	elec	elec
Water heater	mid	mid	mid	mid	mid	mid	mid	mid	elec	elec	elec	elec	elec	elec	elec
Ventilation Equipment	>60%	>60%	>60%	>60%	>60%	>60%	>60%	>60%	>77%	>77%	>77%	>77%	>77%	>77%	>77%

3.5 HOT-2000 Energy Consumption Estimates

The predicted energy consumptions of the Conventional, the Actual R-2000, the Optimized R-2000 and the Prescriptive Standards R-2000 houses are presented in Table 7. For each house, the estimated energy consumption, the R-2000 energy target and a percentage ratio of these amounts is given.

An explanation of anomalies that appear in the data are given below.

1. Actual R-2000 house #14a and #15a show the estimated consumption to be greater than the R-2000 Target. The original house evaluations were carried out using an earlier version of the HOT-2000 computer program.

2. Changes in the R-2000 energy target, as seen with House #7a, for example, result when the builder switches fuel types, such as from gas to electricity, and installs different space and/or water heating appliances. Note that a "*" in the table indicates that no change in the energy target occurred.

3. Using the prescriptive standards to specify R-2000 upgrades resulted in House #11b and #15a consuming more than the R-2000 Energy Target.

4. Three of the Optimized R-2000 houses are well below the R-2000 energy target.

    1. House #7a was a small unit and one-half of a duplex.

    2. Although House #10b has rigid exterior insulation, this is the builder's conventional practice and, therefore, was not removed.

    3. House #12a incorporated a heat pump which was not changed in the Optimized R-2000 house.

Table 7: HOT-2000 ENERGY CONSUMPTION ESTIMATES (* - Denotes no change in R-2000 Energy Target)

	Northern Alberta							Southern Alberta					
	Edmonton							Red Deer		Calgary			
Builder/House Number	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
A. Conventional House													
Estimated Consumption (MJ)	283234	210539	196560	152233	208314	163008	251230	169949	154714	264222	213008	101336	160765
R-2000 Energy Target (MJ)	124031	120078	106283	87592	116737	91048	131933	91062	82760	122472	105703	67896	84431
Estimated/Target (%)	228%	175%	185%	174%	178%	179%	190%	187%	187%	216%	202%	149%	190%
B. Actual R-2000 House													
Estimated Consumption (MJ)	119920	104551	104738	74779	101045	88402	120200	84492	82552	119729	97499	32947	65822
R-2000 Energy Target (MJ)	*	*	*	*	*	*	*	*	*	*	*	45349	*
Estimated/Target (%)	97%	87%	99%	85%	87%	97%	91%	93%	100%	98%	92%	73%	78%
C. Optimized R-2000 House													
Estimated Consumption (MJ)	120463	109620	106067	87469	116359	87412	128520	91033	82706	119945	98309	36990	78062
R-2000 Energy Target (MJ)	*	*	*	*	*	*	*	*	*	*	*	45349	*
Estimated/Target (%)	97%	91%	100%	100%	100%	96%	97%	100%	100%	98%	93%	82%	92%
D. Prescriptive Standards R-2000 House													
Estimated Consumption (MJ)	110876	109620	104411	80507	101930	91436	120362	81886	76266	118184	96451	54655	78062
R-2000 Energy Target (MJ)	*	*	*	*	*	*	*	*	*	*	*	*	*
Estimated/Target (%)	89%	91%	98%	92%	87%	100%	91%	90%	92%	96%	91%	80%	92%

	Saskatchewan								Manitoba						
	Regina			Saskatoon					Winnipeg						
Builder/House Number	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
A. Conventional House															
Estimated Consumption (MJ)	458201	391709	219013	286362	137351	228539	160996	195894	122519	104836	223549	170939	174262	210704	180799
R-2000 Energy Target (MJ)	113562	127728	102078	116903	83578	134028	94385	103608	73865	65466	108396	87329	91224	99644	90857
Estimated/Target (%)	403%	307%	215%	245%	164%	171%	171%	189%	166%	160%	206%	196%	191%	211%	199%
B. Actual R-2000 House															
Estimated Consumption (MJ)	102913	113375	91771	109951	72176	102370	62089	83909	45104	54205	90061	65358	63299	71327	61135
R-2000 Energy Target (MJ)	*	*	*	*	*	*	78581	97808	*	*	92596	60894	64012	70747	63720
Estimated/Target (%)	91%	89%	90%	94%	86%	76%	79%	96%	61%	83%	97%	107%	99%	101%	96%
C. Optimized R-2000 House															
Estimated Consumption (MJ)	111316	123642	101786	116582	77047	111110	85849	103291	45104	64426	90061	60188	63972	70618	63634
R-2000 Energy Target (MJ)	*	*	*	*	*	*	*	*	*	*	92596	60894	64012	70747	63720
Estimated/Target (%)	98%	97%	100%	100%	92%	83%	91%	100%	61%	98%	97%	99%	100%	100%	100%
D. Prescriptive Standards R-2000 House															
Estimated Consumption (MJ)	110282	122324	97222	116240	75226	108860	78865	95602	73861	58550	90886	59227	63299	79330	62582
R-2000 Energy Target (MJ)	*	*	*	*	*	*	78581	97808	*	*	92596	60894	64012	70747	63720
Estimated/Target (%)	97%	96%	95%	99%	90%	81%	100%	109%	100%	89%	98%	97%	99%	112%	98%

3.6 Average Energy Consumption Estimates

The average energy consumption estimates for the Actual R-2000, the Optimized R-2000 and the Prescriptive Standards R-2000 houses are presented in Table 8. The averages have been categorized by city, province and region.

Comments

1. The HOT-2000 program estimated that the conventional house would consume approximately twice the amount of energy specified by the R-2000 Energy Target. The estimated consumption would be approximately three times greater in Regina where the standard practice of the builders interviewed was to leave the basement uninsulated or to insulate with R-12 to two feet below grade.

2. The estimated consumption of the Actual R-2000 house was typically about 90% of the energy target. This figure varied depending upon insulation levels. In Saskatoon, for example, where building envelope insulation levels were high (R-28 walls), this figure dropped to 84%. In Winnipeg, however, where R-20 exterior walls are common, the estimated consumption was 97% of the target.

3. The Optimized R-2000 house was the best method of specifying R-2000 upgrades that would bring the estimated energy consumption as close as possible to the R-2000 energy target and minimize R-2000 costs. This is shown in Section 4.0.

Table 8: AVERAGE ENERGY CONSUMPTION ESTIMATES AS A PERCENTAGE OF R-2000 TARGET

City (# of Homes)	High (%)	Low (%)	Average (%)	Province	Average (%)	Region	Average (%)
A. Conventional House							
Edmonton (7)	228	174	**187**	Alberta (13)	**188**		
Calgary/Red Deer (6)	216	149	**188**				
Regina (4)	403	190	**292**	Saskatchewan (8)	**233**	Prairies (27)	**205**
Saskatoon (4)	245	164	**174**				
Winnipeg (6)	206	160	**194**	Manitoba (6)	**194**		
B. Actual R-2000 House							
Edmonton (7)	99	85	**92**	Alberta (13)	**92**		
Calgary/Red Deer (6)	100	73	**89**				
Regina (4)	91	78	**91**	Saskatchewan (8)	**88**	Prairies (27)	**92**
Saskatoon (4)	94	76	**84**				
Winnipeg (6)	107	61	**97**	Manitoba (6)	**97**		
C. Optimized R-2000 House							
Edmonton (7)	100	91	**97**	Alberta (13)	**96**		
Calgary/Red Deer (6)	100	82	**94**				
Regina (4)	98	92	**99**	Saskatchewan (8)	**95**	Prairies (27)	**97**
Saskatoon (4)	100	83	**91**				
Winnipeg (6)	100	61	**99**	Manitoba (6)	**99**		
D. Prescriptive Standards R-2000 House							
Edmonton (7)	98	87	**93**	Alberta (13)	**92**		
Calgary/Red Deer (6)	100	80	**90**				
Regina (4)	97	92	**97**	Saskatchewan (8)	**96**	Prairies (27)	**96**
Saskatoon (4)	99	81	**95**				
Winnipeg (6)	109	89	**99**	Manitoba (6)	**99**		

3.7 Actual Energy Consumption Information

In order to establish the credibility of the estimated energy consumption figures presented in the previous section, actual energy information was gathered from local utilities on 31 R-2000 and non-R2000 homes that had identical, or very similar, designs. The comparison energy data was compiled for the period from September, 1987 to March, 1988 (which was common to all of the houses) and is presented in Table 9.

Comments

1. Eleven house groups appear on the table. Each group represents identical or similar houses built to a particular builder's R-2000 or non-R2000 standard. Houses within a group that are an identical design have been denoted with a "*".

2. Although the comparison homes are different from the Actual R-2000 houses studied in this project, it can be seen that the actual energy consumption differences between the comparison R-2000 and non-R2000 homes are of the same magnitude as the predicted energy consumption differences of the Actual R-2000 and Conventional study houses. For example, the non-R2000 house in Edmonton Group #1 consumed 195% more energy as an identical house built to R-2000 specifications. The average predicted value for the Actual R-2000 houses in Edmonton was 188%.

3. Lifestyle is an important factor that can cause actual energy consumption figures to be very different from HOT-2000 estimates. In Group #11, for example, one of the non-R2000 houses consumed *more* than the two identical R-2000 houses.

Table 9: ACTUAL ENERGY CONSUMPTION INFORMATION - September 1987 to March 1988

(* - Denotes identical house models)

Location	Type	House Groups	Size (ft^2)	Gas Consumption (MJ/day)	Electricity Consumption (MJ/day)	Total Consumption (MJ/day)
1. Edmonton	Bungalow	R-2000	1521	261	109	370
	Bungalow	*R-2000	1201	268	100	368
	Bungalow	*Conventional	1201	596	122	718
2. Edmonton	2-Storey	R-2000	1948	351	134	485
	Split	Conventional	2107	479	42	521
	2-Storey	Conventional	2107	430	60	490
3. Edmonton	2-Storey	R-2000	2450	408	164	572
	2-Storey	Conventional	2455	616	45	661
	2-Storey	R-2000	2500	376	110	486
	2-Storey	Conventional	2500	669	86	755
4. Calgary	Bungalow	R-2000	1550	400	143	543
	Bungalow	Conventional	1500	276	47	323
5. Calgary	2-Storey	R-2000	2100	363	84	447
	2-Storey	Conventional	2008	626	116	742
	2-Storey	Conventional	2100	628	104	732
6. Calgary	2-Storey	R-2000	2400	560	108	668
	2-Storey	Conventional	2400	670	74	744
7. Regina	Bungalow	*R-2000	1592	214	116	330
	Bungalow	*Conventional	1592	639	70	709
	Bungalow	*Conventional	1592	653	100	753
8. Regina	2-Storey	*R-2000	1660	364	92	456
	2-Storey	*Conventional	1660	637	86	723
9. Saskatoon	Bungalow	*R-2000	1108	213	n/a	213
	Bungalow	*Conventional	1108	394	n/a	394
10. Pr. Albert	Bilevel	*R-2000	1202	285	129	414
	Bilevel	*Conventional	1202	300	130	430
11. Pr. Albert	Bilevel	*R-2000	1280	307	150	457
	Bilevel	*R-2000	1280	334	194	528
	Bilevel	*Conventional	1280	278	116	394
	Bilevel	*Conventional	1280	438	128	566

4.0 TOTAL INCREMENTAL COSTS

Section 4.0 details the incremental costs incurred as the builders upgraded their Conventional house to the specifications detailed in Section 3.0 for the Actual R-2000, Optimized R-2000 and Prescriptive Standards R-2000 houses. The incremental cost of each component that contributes to the total incremental cost is detailed in this section.

4.1 Incremental Cost of House Components

Incremental costs are reported for the Actual R-2000, the Optimized R-2000 and the Prescriptive Standards R-2000 houses in three categories - the building envelope, the mechanical systems and other costs. Each category comprises a number of building components.

The builders provided the incremental cost of upgrading their conventional standards to construct their Actual R-2000 houses. This cost information was used with the construction specifications for the Optimized R-2000 and the Prescriptive Standards R-2000 houses to determine the incremental cost required to construct each of those houses.

The incremental cost of each component of the Actual R-2000 house is presented in Tables 10a and 10b. The total incremental costs and the total construction costs for the Actual R-2000, Optimized R-2000 and Prescriptive Standards R-2000 houses are also presented. **The construction costs presented here do not include the price of land or the builder's overhead and profit.**

In addition, the total incremental costs are reported as a percentage of the total construction cost and in relation to the total costs of building the Actual R-2000 and the Prescriptive Standards R-2000 houses.

The builders' reported costs were verified using estimates prepared by an Edmonton-based quantity surveyor. If quantity surveyor information was not available for a particular component, the cost reported by the builder was used. All differences noted can be attributed directly to different material costs and labour rates in each center, indicating that the reported costs are accurate. The comparison data is included in Appendix C.

An explanation of anomalies that appear in the data are given below.

1. The incremental costs for Optimized R-2000 house #14a were greater than the Actual R-2000 house because the R-2000 house required upgrades in order to meet the R-2000 energy target of the latest version of the HOT-2000 program.

2. The costs for the *Space Heating* component of House #7a, #14a, #14b, #15a and #15b and the *Water Heating* component of House #13 appear negative because the builders saved money on installation charges by using electricity in their R-2000 houses rather than natural gas.

3. Negative values for the *Reduction in Incremental Costs* for either an Optimized R-2000 or Prescriptive Standards R-2000 house indicates that that particular house cost more to build than the Actual R-2000 house.

Comments

1. The higher cost of installing Glasclad on the exterior walls of House #15a and #15b compared to installing Styrofoam on the same houses was due mainly to the extra framing costs related to providing backing around windows, doors, at corners, etc.

2. The combined cost of triple glazing and a high efficiency heat recovery ventilator is significantly less than the cost of exterior insulation and still allows the builder to meet the R-2000 energy target.

3. The high air sealing costs reported by Builder #6 were due to the builder being overcharged (relative to other builders) by the trade responsible for this work.

4. As the Actual R-2000 house is optimized, the incremental cost of the building envelope decreases but the cost of the mechanical system remains constant and becomes the major portion of the total incremental cost. Further, the incremental cost of the mechanical system does not change significantly with the size of the house which means the purchaser of a smaller home incurs much the same mechanical system cost as the large home buyer.

Table 10a: INCREMENTAL COST OF UPGRADING CONVENTIONAL HOUSE TO ACTUAL R-2000 SPECIFICATIONS

	Northern Alberta							Southern Alberta					
	Edmonton							Red Deer		Calgary			
Builder/House Number	1a	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
CONVENTIONAL HOUSE COST ($)	103000	110340	92700	52844	86360	90100	127200	67000	69400	105847	81540	36200	69000
Building Envelope													
Slab/Foundation	0	652	0	451	149	0	480	0	0	0	0	196	272
Basement Walls	181	170	163	165	174	146	182	0	0	201	151	274	456
Rim Joist	785	657	288	228	343	0	0	0	0	150	170	146	224
Cantilevers	0	0	0	23	17	0	0	0	0	0	0	0	0
Exterior Walls	0	1100	548	700	654	1495	2234	0	0	2232	1529	241	478
Attic/Roof	0	448	306	205	143	135	225	0	405	187	227	358	419
Windows (incl.jamb ext.)	1750	300	150	589	970	1172	1171	663	698	140	120	123	717
Exterior Doors	0	0	0	0	0	0	0	0	0	0	0	0	0
Air Sealing	428	370	300	170	52	50	75	435	314	612	622	311	386
Sub-total	3144	3697	1755	2531	2502	2998	4367	1098	1417	3522	2819	1649	2952
Mechanical System													
Space Heating	1700	0	0	0	60	0	0	500	500	500	500	-460	500
Water Heating	420	400	400	420	420	500	500	600	600	450	450	0	450
Ventilation Equipment	1380	1670	1700	1385	1430	1300	1300	1110	1110	1550	1470	1080	1195
Sub-total	3500	2070	2100	1805	1910	1800	1800	2210	2210	2500	2420	620	2145
Other Costs													
Air test	180	200	200	200	200	180	180	200	200	200	200	350	350
Supervision	200	200	200	0	0	0	0	42	42	160	160	0	0
Administration	0	500	500	0	0	0	0	0	0	0	0	0	0
Sub-total	380	900	900	200	200	180	180	242	242	360	360	350	350
Incremental Cost Of Actual R-2000 House													
ACTUAL INCRE. COSTS	7024	6667	4755	4536	4612	4978	6347	3550	3869	6382	5599	2619	5447
ACTUAL CONSTRUCTION COSTS	110024	117007	97455	57380	90972	95078	133547	70550	73269	112229	87139	38819	74447
% INCREMENTAL COSTS	6.4%	5.7%	4.9%	7.9%	5.1%	5.2%	4.8%	5.0%	5.3%	5.7%	6.4%	6.7%	7.3%
Incremental Cost Of Optimized vs Actual R-2000 House													
OPTIMIZED INCRE. COSTS	5964	4367	4534	3136	3219	3733	3883	3131	3066	4106	3908	1768	3482
OPT. CONSTRUCTION COSTS	109964	114707	97234	55980	89579	93833	131083	70131	72466	109953	85448	37968	72482
% INCREMENTAL COSTS	5.5%	3.8%	4.7%	5.6%	3.6%	4.0%	3.0%	4.5%	4.2%	3.7%	4.6%	4.7%	4.8%
INCREMENTAL COST SAVINGS	1060	2300	221	1400	1393	1245	2464	419	803	2276	1691	851	1965
REDUCTION IN INCRE. COSTS	15.1%	34.5%	4.6%	30.9%	30.2%	25.0%	38.8%	11.8%	20.8%	35.7%	30.2%	32.5%	36.1%
Incremental Cost Of Prescriptive Standards vs Actual R-2000 House													
PRESCRIP. INCRE. COSTS	6961	5807	4657	3585	3866	3683	5150	3364	3276	4207	4050	2728	3482
PRESCRIP. CONSTUC. COSTS	109961	116147	97357	56429	90226	93783	132350	70364	72676	110054	85590	38928	72482
% INCREMENTAL COSTS	6.3%	5.0%	4.8%	6.4%	4.3%	3.9%	3.9%	4.8%	4.5%	3.8%	4.7%	7.0%	4.8%
INCREMENTAL COST SAVINGS	63	860	98	951	746	1295	1197	186	593	2175	1549	-109	1965
REDUCTION IN INCRE. COSTS	.9%	12.9%	2.1%	21.0%	16.2%	26.0%	18.9%	5.2%	15.3%	34.1%	27.7%	-4.2%	36.1%

Table 10b: INCREMENTAL COST OF UPGRADING CONVENTIONAL HOUSE TO ACTUAL R-2000 SPECIFICATIONS

	Saskatchewan								Manitoba						
	Regina		Saskatoon						Winnipeg						
Builder/House Number	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
CONVENTIONAL HOUSE COST ($)	112900	102800	72900	81200	64400	140600	53890	91830	91000	115000	110400	61200	63860	105000	97600
Building Envelope															
Slab/Foundation	100	100	0	0	0	0	197	0	0	395	0	0	0	595	48
Basement Walls	1754	1397	1210	1382	0	0	0	0	0	900	200	286	238	1138	1018
Rim Joist	137	0	100	105	0	0	0	0	0	0	400	125	125	122	89
Cantilevers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exterior Walls	1925	0	0	0	0	0	309	585	0	944	0	0	0	2102	1324
Attic/Roof	500	0	0	0	0	0	255	271	0	175	0	0	69	278	290
Windows (incl.jamb ext.)	1000	763	432	524	0	0	100	100	0	285	0	0	0	312	572
Exterior Doors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Air Sealing	430	320	221	292	250	250	250	250	0	0	0	350	350	250	250
Sub-total	5846	2580	1963	2303	250	250	1111	1206	0	2699	600	761	782	4797	3591
Mechanical System															
Space Heating	600	1800	1340	1265	1500	1500	350	350	5549	1076	200	-475	-475	-345	-335
Water Heating	500	500	515	515	450	450	0	0	0	0	-60	0	0	0	0
Ventilation Equipment	1000	1350	1450	1500	1275	1275	1200	1200	1650	1650	1300	1092	1618	2195	2045
Sub-total	2100	3650	3305	3280	3225	3225	1550	1550	7199	2726	1440	617	1143	1850	1710
Other Costs															
Air test	150	150	150	150	150	150	150	150	110	110	75	125	125	150	150
Supervision	0	0	0	0	0	0	100	100	0	0	0	30	30	30	30
Administration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	150	150	150	150	150	150	250	250	110	110	75	155	155	180	180
Incremental Cost Of Actual R-2000 House															
ACTUAL INCRE. COSTS	8096	6380	5418	5733	3625	3625	2911	3006	7309	5535	2115	1533	2080	6827	5481
ACTUAL CONSTRUCTION COSTS	120996	109180	78318	86933	68025	144225	56801	94836	98309	120535	112515	62733	65940	111827	103081
% INCREMENTAL COSTS	6.7%	5.8%	6.9%	6.6%	5.3%	2.5%	5.1%	3.2%	7.4%	4.6%	1.9%	2.4%	3.2%	6.1%	5.3%
Incremental Cost Of Optimized vs Actual R-2000 House															
OPTIMIZED INCRE. COSTS	4884	5377	4208	4444	2625	2625	2550	2600	7309	4108	2115	1859	2011	5414	3295
OPT. CONSTRUCTION COSTS	117784	108177	77108	85644	67025	143225	56440	94430	98309	119108	112515	63059	65871	110414	100895
% INCREMENTAL COSTS	4.1%	5.0%	5.5%	5.2%	3.9%	1.8%	4.5%	2.8%	7.4%	3.4%	1.9%	2.9%	3.1%	4.9%	3.3%
INCREMENTAL COST SAVINGS	3212	1003	1210	1289	1000	1000	361	406	0	1427	0	-326	69	1413	2186
REDUCTION IN INCRE. COSTS	39.7%	15.7%	22.3%	22.5%	27.6%	27.6%	12.4%	13.5%	.0%	25.8%	.0%	-21.3%	3.3%	20.7%	39.9%
Incremental Cost Of Prescriptive Standards vs Actual R-2000 House															
PRESCRIP. INCRE. COSTS	5393	4830	4702	5190	2777	2749	3139	3366	7526	4238	2177	1908	2080	5136	3640
PRESCRIP. CONSTUC. COSTS	118297	107630	77602	86590	67177	143349	57029	95196	98526	119238	112577	63108	65940	110136	101240
% INCREMENTAL COSTS	4.6%	4.5%	6.1%	6.0%	4.1%	1.9%	5.5%	3.5%	7.6%	3.6%	1.9%	3.0%	3.2%	4.7%	3.6%
INCREMENTAL COST SAVINGS	2703	1550	716	543	848	876	-228	-360	-217	1297	-62	-375	0	1691	1841
REDUCTION IN INCRE. COSTS	33.4%	24.3%	13.2%	9.5%	23.4%	24.2%	-7.8%	-12.0%	-3.0%	23.4%	-2.9%	-24.5%	.0%	24.8%	33.6%

4.2 Average Incremental Costs

The average incremental cost of the Actual R-2000, the Optimized R-2000 and the Prescriptive Standards R-2000 house is presented in Table 11 as a percentage of the total construction cost. The average incremental savings of the Optimized and Prescriptive Standards R-2000 houses compared to the Actual R-2000 houses are also given and are categorized by city, province and region. This information would be of special interest to builders in a competitive market interested in building more R-2000 houses.

Comments

1. House #12a has not been included in the averaging process. This house was not typical of R-2000 housing since the builder simply installed a heat pump into his Conventional house. The high cost of the heat pump made the incremental costs of this house high compared to what was typically built in the Winnipeg area. Including this house would have resulted in raising the average incremental cost figures significantly.

2. The higher incremental cost percentage in Regina was due to the lack of basement insulation in the Conventional houses. The entire cost of framing and insulating an R-20 basement wall became an R-2000 incremental cost.

3. The lower incremental cost percentage in Saskatoon and Winnipeg resulted from the higher conventional building standards that exist in these centers (see Table 3b). Triple glazing, for example, was standard in both cities.

4. The provincial average for Saskatchewan presents a less accurate picture of the actual incremental cost percentage for each city since the conventional construction standards in Regina and Saskatoon were very different. This was not the case in Alberta where conventional standards in the three different centers were relatively similar.

5. The average incremental savings for the Optimized R-2000 house ranged from 27.8% in Calgary/Red Deer to 12.7% in Winnipeg due to different building standards in each area. The wide range emphasizes the need for caution when interpreting these savings beyond the local level.

6. The incremental cost of the Prescriptive Standards R-2000 house averaged approximately 10% higher than the Optimized R-2000 houses in Alberta and Saskatchewan and 4% higher in Manitoba. Note again the wide variations.

Table 11: AVERAGE INCREMENTAL COST SUMMARY

A. Actual R-2000 House: Average Incremental Cost As % Of Builder Cost

City (# of Homes)	High (%)	Low (%)	Average (%)	Province	Average (%)	Region	Average (%)
Edmonton (7)	7.9	4.8	5.7	Alberta (13)	5.9		
Calgary/Red Deer (6)	7.3	5.0	6.1				
Regina (4)	6.9	5.7	6.5	Saskatchewan (8)	5.3	Prairies (27)	5.2
Saskatoon (4)	5.3	2.5	4.0				
Winnipeg (6)	6.1	1.9	4.4	Manitoba (6)	4.4		

B. Optimized R-2000 House: Average Incremental Cost As % Of Builder Cost

City (# of Homes)	High (%)	Low (%)	Average (%)	Province	Average (%)	Region	Average (%)
Edmonton (7)	5.6	3.0	4.3	Alberta (13)	4.4		
Calgary/Red Deer (6)	4.8	3.7	4.4				
Regina (4)	5.5	4.1	5.0	Saskatchewan (8)	4.2	Prairies (27)	4.1
Saskatoon (4)	4.5	1.8	3.3				
Winnipeg (6)	4.9	1.9	3.7	Manitoba (6)	3.7		
			Average Incremental Savings Over Actual R-2000 House				
Edmonton (7)	38.8	4.6	25.6	Alberta (13)	26.7		
Calgary/Red Deer (6)	36.1	11.8	27.8				
Regina (4)	39.7	15.7	25.1	Saskatchewan (8)	22.7	Prairies (27)	20.7
Saskatoon (4)	27.6	12.4	20.3				
Winnipeg (6)	39.9	0	12.7	Manitoba (7)	12.7		

C. Prescriptive Standards R-2000 House: Average Incremental Cost As % Of Builder Cost

City (# of Homes)	High (%)	Low (%)	Average (%)	Province	Average (%)	Region	Average (%)
Edmonton (7)	6.8	3.7	5.3	Alberta (13)	5.2		
Calgary/Red Deer (6)	7.0	3.9	5.0				
Regina (4)	6.1	4.6	5.6	Saskatchewan (8)	4.7	Prairies (27)	4.6
Saskatoon (4)	5.2	1.9	3.7				
Winnipeg (6)	4.7	1.9	3.8	Manitoba (6)	3.8		
			Average Incremental Savings Over Actual R-2000 House				
Edmonton (7)	26.0	.9	14.0	Alberta (13)	16.5		
Calgary/Red Deer (6)	36.1	-4.2	19.0				
Regina (4)	33.4	9.5	20.1	Saskatchewan (8)	13.5	Prairies (27)	12.9
Saskatoon (4)	24.2	-12.0	6.9				
Winnipeg (6)	33.6	-15.1	8.7	Manitoba (7)	8.7		

5.0 NORMALIZED INCREMENTAL COSTS

5.1 Incremental Component Cost/Area

Using the developed floor area of each house, the R-2000 incremental cost information presented in Tables 10a and 10b was normalized to give the incremental cost per square foot to construct the Actual R-2000, the Optimized R-2000 and the Prescriptive Standards R-2000 houses. This information is presented in Tables 12a and 12b. The contribution of each component of the Actual R-2000 house to the total incremental cost is also shown in these tables.

The developed floor area, which does not include the basement, was used since this is the area that appears on floor plans and the area that is commonly used when speaking of a "1500 square foot (ft^2) bungalow or a 2400 ft^2 two-storey". The total floor area, which includes the developed floor area plus the basement floor area, is given in Table 2. The volume of each house is included in the tables to assist the reader in determining the relative size of each house.

The following anomalies require further explanation.

1. The costs per square foot for House #12a were high because of the high cost of the heat pump that was installed.

2. The normalized costs for the *Space Heating* component of House #7a, #15a and #15b and the *Water Heating* component of House #13 appear negative because the builders saved money on installation charges by using electricity in their R-2000 houses rather than natural gas.

Comments

1. The information on these tables is most valuable if used on an individual house basis. Using *Table 2: R-2000 House Information* and *Table 4: Builders Upgrade to R-2000 Specifications*, the reader is able to combine a house type with specific R-2000 upgrades and subsequently estimate an incremental cost.

2. The figures on these tables are very sensitive to house size. Consider the houses constructed by Builder #11. Table 4b shows that the R-2000 upgrades in each house were very similar. Table 12b shows that House #11b has a larger area and volume than House #11a but the incremental costs are almost the same. As a result, the incremental costs for House #11a, the smaller house, are $1.04 more per square foot of developed floor area than House #11b.

Table 12a: INCREMENTAL COST/AREA OF R-2000 HOUSES AND COMPONENTS ($/ft²)

	Northern Alberta Edmonton							Southern Alberta Red Deer		Calgary			
	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Incremental Cost/Area Of Actual R-2000 House And Components ($/ft²)													
INCREMENTAL COST ($)	7024	6667	4755	4536	4612	4978	6347	3550	3869	6382	5599	2619	5447
DEVELOPED HOUSE AREA (ft²)	2250	2452	2060	1201	2159	1700	2400	1563	2171	2402	1865	840	2316
HOUSE VOLUME (ft³)	31350	29975	25162	18641	28810	19846	34111	19979	17063	32386	25994	12256	18264
Building Envelope													
Slab/Foundation	0	.27	0	.38	.07	0	.20	0	0	0	0	.23	.12
Basement Walls	.08	.07	.08	.14	.08	.09	.08	0	0	.08	.08	.33	.20
Rim Joist	.35	.27	.14	.19	.16	0	0	0	0	.06	.09	.17	.10
Cantilevers	0	0	0	.02	.01	0	0	0	0	0	0	0	0
Exterior Walls	0	.45	.27	.58	.30	.88	.93	0	0	.93	.92	.29	.21
Attic/Roof	0	.18	.15	.17	.07	.08	.09	0	.19	.08	.12	.43	.18
Windows (incl. jamb ext.)	.78	.12	.07	.49	.45	.69	.49	.42	.32	.06	.06	.15	.31
Exterior Doors	0	0	0	0	0	0	0	0	0	0	0	0	0
Air Sealing	.19	.15	.15	.14	.02	.03	.03	.28	.14	.25	.33	.37	.17
Sub-total	1.49	1.51	.85	2.11	1.16	1.76	1.82	.70	.65	1.47	1.51	1.96	1.27
Mechanical System													
Space Heating	.76	0	0	0	.03	0	0	.32	.23	.21	.27	-.55	.22
Water Heating	.19	.16	.19	.35	.19	.29	.21	.38	.28	.19	.24	0	.19
Ventilation Equipment	.61	.68	.83	1.15	.66	.76	.54	.71	.51	.65	.79	1.29	.52
Sub-total	1.56	.84	1.02	1.50	.88	1.06	.75	1.41	1.02	1.04	1.30	.74	.93
Other Parameters													
Air test	.08	.08	.10	.17	.09	.11	.08	.13	.09	.08	.11	.42	.15
Supervision	.09	.08	.13	[illegible]	0	0	0	.03	.02	.07	.09	0	0
Administration	0	.20	.24	0	0	0	0	0	0	0	0	0	0
Sub-total	.17	.37	.44	.17	.09	.11	.08	.15	.11	.15	.19	.42	.15
R-2000 AREA COSTS ($/ft²)	3.12	2.72	2.31	3.78	2.14	2.93	2.64	2.27	1.78	2.66	3.00	3.12	2.35
Incremental Cost/Area of Optimized R-2000 House													
OPTIMIZED INCRE. COSTS ($)	5964	4367	4534	3136	3219	3723	3883	3131	3066	4106	3908	1768	3481
OPTIMIZED AREA COSTS ($/ft²)	2.65	1.78	2.20	2.61	1.49	2.20	1.62	2.00	1.41	1.71	2.10	2.10	1.50
Incremental Cost/Area of Prescriptive R-2000 Standards House													
PRESCRIP. INCRE. COSTS ($)	6961	5807	4657	3385	3866	3683	5150	3364	3276	4207	4050	3728	3482
PRESCRIP. AREA COSTS ($/ft²)	3.09	2.37	2.26	2.99	1.79	2.17	2.15	2.15	1.51	1.75	2.17	2.25	1.50

Table 12a: INCREMENTAL COST/AREA OF R-2000 HOUSES AND COMPONENTS ($/ft²)

	Saskatchewan Regina		Saskatoon						Manitoba Winnipeg					
	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
Incremental Cost/Area Of Actual R-2000 House And Components ($/ft²)															
INCREMENTAL COST ($)	8096	6780	5418	5733	3625	3625	2911	3006	7309	5535	2115	1533	2080	6827	5481
DEVELOPED HOUSE AREA (ft²)	1720	2300	1660	1850	1050	2475	1108	1888	1343	1505	2373	1700	1775	1808	1330
HOUSE VOLUME (ft³)	26271	30970	22492	27401	15967	32269	19461	22443	23076	19584	24692	17684	18980	21781	18858
Building Envelope															
Slab/Foundation	.06	.04	0	0	0	0	.18	0	0	.26	0	0	0	.33	.04
Basement Walls	1.02	.50	.73	.75	0	0	0	0	0	.60	.08	.17	.13	.63	.77
Rim Joist	.08	0	.06	.06	0	0	0	0	0	0	.17	.07	.07	.07	.07
Cantilevers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exterior Walls	1.12	0	0	0	0	0	.28	.31	0	.63	0	0	0	1.16	1.00
Attic/Roof	.29	0	0	0	0	0	.23	.14	0	.12	0	0	.04	.15	.22
Windows (incl. jamb ext.)	.58	.27	.26	.28	0	0	.09	.05	0	.19	0	0	0	.17	.43
Exterior Doors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Air Sealing	.25	.11	.13	.16	.24	.10	.23	.13	0	0	0	.21	.20	.14	.19
Sub-total	3.40	.92	1.18	1.24	.24	.10	1.00	.64	0	1.79	.25	.45	.44	2.65	2.70
Mechanical System															
Space Heating	.35	.64	.81	.68	1.43	.61	.32	.19	4.13	.71	.08	-.29	-.27	-.19	-.25
Water Heating	.25	.18	.31	.28	.43	.18	0	0	0	0	-.03	0	0	0	0
Ventilation Equipment	.58	.48	.87	.81	1.21	.52	1.08	.64	1.23	1.10	.55	.64	.91	1.21	1.54
Sub-total	1.22	1.30	1.99	1.77	3.07	1.30	1.40	.82	5.36	1.81	.61	.36	.64	1.02	1.29
Other Parameters															
Air test	.09	.05	.09	.08	.14	.06	.14	.08	.08	.07	.03	.07	.07	.08	.11
Supervision	0	0	0	0	0	0	.09	.05	0	0	0	.02	.02	.02	.02
Administration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	.09	.05	.09	.08	.14	.06	.23	.13	.08	.07	.03	.09	.09	.10	.14
R-2000 AREA COSTS ($/ft²)	4.71	2.28	3.26	3.10	3.45	1.46	2.63	1.59	5.44	3.68	.89	.90	1.17	3.78	4.12
Incremental Cost/Area of Optimized R-2000 House															
OPTIMIZED INCRE. COSTS ($)	4884	5077	4208	4444	2625	2625	2550	2600	7309	4108	2115	1859	2011	5414	3295
OPTIMIZED AREA COSTS ($/ft²)	2.84	1.92	2.53	2.40	2.50	1.06	2.30	1.38	5.44	2.73	.89	1.09	1.13	2.99	2.48
Incremental Cost/Area of Prescriptive R-2000 Standards House															
PRESCRIP. INCRE. COSTS ($)	5393	4830	4702	5190	2777	2749	3139	3366	7526	4238	2177	1908	2080	5176	3649
PRESCRIP. AREA COSTS ($/ft²)	3.14	1.77	2.83	2.81	2.64	1.11	2.83	1.78	5.60	2.82	.92	1.12	1.17	2.84	2.74

5.2 Average Component Cost/Area

Table 13 presents the averaged incremental cost per developed floor area. Although this information can be useful for estimating the incremental cost for a particular house size, it must be interpreted with a clear understanding of the different specifications of the houses investigated.

Comments

1. As mentioned above, this information is very sensitive to the individual characteristics of each house. For example, the average incremental cost per square foot for an R-2000 house in Saskatoon is $2.28. Notice, however, that the range is from $1.46 to $3.45 per square foot.

2. The Optimized R-2000 house averages are more reliable to use because the building envelope upgrades show less variation. Once again, however, the size of the house can affect these figures dramatically since the high cost of equipment upgrades, such as the heat recovery ventilator, remain constant whether the house is large or small causing the incremental cost per square foot to be subsequently higher.

Table 13: AVERAGE INCREMENTAL COST/AREA

City (# of Homes)	High ($/ft²)	Low ($/ft²)	Average ($/ft²)	Province	Average ($/ft²)	Region	Average ($/ft²)
A. Actual R-2000 House							
Edmonton (7)	3.78	2.14	**2.80**	Alberta (13)	**2.82**		
Calgary/Red Deer (6)	4.71	1.78	**2.84**				
Regina (3)	3.26	2.28	**2.88**	Saskatchewan (7)	**2.58**	Prairies (26)	**2.67**
Saskatoon (4)	3.45	1.46	**2.28**				
Winnipeg (6)	4.12	.89	**2.61**	Manitoba (6)	**2.61**		
B. Optimized R-2000 House							
Edmonton (7)	2.65	1.49	**2.08**	Alberta (13)	**2.02**		
Calgary/Red Deer (6)	2.84	1.41	**1.95**				
Regina (3)	2.53	1.92	**2.29**	Saskatchewan (7)	**2.05**	Prairies (26)	**2.04**
Saskatoon (4)	2.50	1.06	**1.81**				
Winnipeg (6)	2.99	.89	**2.07**	Manitoba (6)	**2.07**		
B. Prescriptive Standards R-2000 House							
Edmonton (7)	3.09	1.79	**2.40**	Alberta (13)	**2.31**		
Calgary/Red Deer (6)	3.25	1.50	**2.21**				
Regina (3)	2.83	1.73	**2.45**	Saskatchewan (7)	**2.27**	Prairies (26)	**2.23**
Saskatoon (4)	2.83	1.11	**2.09**				
Winnipeg (6)	2.84	.92	**2.12**	Manitoba (6)	**2.12**		

5.3 Incremental Component Cost/Total Cost

The incremental cost of each component used in the Actual R-2000 house is given as a percentage of the total incremental cost in Tables 14a and 14b. The tables quickly identify the more expensive upgrades.

The following anomalies require further explanation.

1. The *Mechanical System* figures for House #12a are high because the builder used a heat pump and upgraded only the mechanical system of his conventional standard.

2. The normalized costs for the *Space Heating* component of House #7a, #15a and #15b and the *Water Heating* component of House #13 appear negative because the builders saved money on installation charges by using electricity in their R-2000 houses rather than natural gas.

Comments

1. The Heat Mirror windows and the high efficiency furnaces in House #1 each accounted for 25% of the incremental costs.

2. Exterior rigid insulation on the main walls of House #6a accounted for 35% of the incremental costs.

3. In Manitoba, where building envelope standards are higher, the heat recovery ventilator in House #13 accounted for 62% of the extra cost of that home.

4. Only one builder reported administration costs for his R-2000 homes.

5. Supervision costs were generally associated with the extra care required to ensure the integrity of the air/vapour barrier.

Table 14a: COMPONENT COSTS OF ACTUAL R-2000 HOUSE AS A PERCENTAGE OF THE TOTAL INCREMENTAL COST

	Northern Alberta							Southern Alberta					
	Edmonton							Red Deer		Calgary			
Builder/House Number	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
ACTUAL INCRE. COSTS ($)	7024	6667	4755	4536	4612	4978	6347	3550	3869	6382	5599	2619	5447
Building Envelope													
Slab/Foundation	0	9.8	0	9.9	3.2	0	7.6	0	0	0	0	7.5	5.0
Basement Walls	2.6	2.5	3.4	3.6	3.8	2.9	2.9	0	0	3.1	2.7	10.5	8.4
Rim Joist	11.2	9.9	6.1	5.0	7.4	0	0	0	0	2.4	3.0	5.6	4.1
Cantilevers	0	0	0	.5	.4	0	0	0	0	0	0	0	0
Exterior Walls	0	16.5	11.5	15.4	14.2	30.0	35.2	0	0	35.0	27.3	9.2	8.8
Attic/Roof	0	6.7	6.4	4.5	3.1	2.7	3.5	0	10.5	2.9	4.1	13.7	7.7
Windows (incl.,amb ext.)	24.9	4.5	3.2	13.0	21.0	23.5	18.4	18.7	18.0	2.2	2.1	4.7	13.2
Exterior Doors	0	0	0	0	0	0	0	0	0	0	0	0	0
Air Sealing	6.1	5.5	6.3	3.7	1.1	1.0	1.2	12.3	8.1	9.6	11.1	11.9	7.1
Sub-total	44.8	55.5	36.9	55.8	54.2	60.2	68.8	30.9	36.6	55.2	50.4	63.0	54.2
Mechanical System													
Space Heating	24.2	0	0	0	1.3	0	0	14.1	12.9	7.8	8.9	-17.6	9.2
Water Heating	6.0	6.0	8.4	9.3	9.1	10.0	7.9	16.9	15.5	7.1	8.0	0	8.3
Ventilation Equipment	19.6	25.0	35.8	30.5	31.0	26.1	20.5	31.3	28.7	24.3	26.3	41.2	21.9
Sub-total	49.8	31.0	44.2	39.8	41.4	36.2	28.4	62.3	57.1	39.2	43.2	23.7	39.4
Other Parameters													
Air test	2.6	3.0	4.2	4.4	4.3	3.6	2.8	5.6	5.2	3.1	3.6	13.4	6.4
Supervision	2.8	3.0	4.2	0	0	0	0	1.2	1.1	2.5	2.9	0	0
Administration	0	7.5	10.5	0	0	0	0	0	0	0	0	0	0
Sub-total	5.4	13.5	18.9	4.4	4.3	3.6	2.8	6.8	6.3	5.6	6.4	13.4	6.4

Table 14b: COMPONENT COSTS OF ACTUAL R-2000 HOUSE AS A PERCENTAGE OF THE TOTAL INCREMENTAL COST

	Saskatchewan Regina		Saskatoon						Manitoba Winnipeg						
Builder/House Number	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
ACTUAL INCRE. COSTS ($)	8096	6380	5418	5733	3625	3625	2911	3006	7309	5535	2115	2483	3030	6827	5481
Building Envelope															
Slab/Foundation	1.2	1.6	0	0	0	0	6.8	0	0	7.1	0	0	0	8.7	.9
Basement Walls	21.7	21.9	22.3	24.1	0	0	0	0	0	16.3	9.5	11.5	7.9	16.7	18.6
Rim Joist	1.7	0	1.8	1.8	0	0	0	0	0	0	18.9	5.0	4.1	1.8	1.6
Cantilevers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exterior Walls	23.8	0	0	0	0	0	10.6	19.5	0	17.1	0	0	0	30.8	24.2
Attic/Roof	6.2	0	0	0	0	0	8.8	9.0	0	3.2	0	0	2.3	4.1	5.3
Windows (incl.,amb ext.)	12.4	12.0	8.0	9.1	0	0	3.4	3.3	0	5.1	0	0	0	4.6	10.4
Exterior Doors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Air Sealing	5.3	5.0	4.1	5.1	6.9	6.9	8.6	8.3	0	0	0	14.1	11.6	3.7	4.6
Sub-total	72.2	40.4	36.2	40.2	6.9	6.9	38.2	40.1	0	48.8	28.4	30.6	25.8	70.3	65.5
Mechanical System															
Space Heating	7.4	28.2	24.7	22.1	41.4	41.4	12.0	11.6	75.9	19.4	9.5	19.1	15.7	-5.1	-6.1
Water Heating	6.2	7.8	9.5	9.0	12.4	12.4	0	0	0	0	-2.8	0	0	0	0
Ventilation Equipment	12.4	21.2	26.8	26.2	35.2	35.2	41.2	39.9	22.6	29.8	61.5	44.0	53.4	32.2	37.3
Sub-total	25.9	57.2	61.0	57.2	89.0	89.0	53.2	51.6	98.5	49.3	68.1	63.1	69.1	27.1	31.2
Other Parameters															
Air test	1.9	2.4	2.8	2.6	4.1	4.1	5.2	5.0	1.5	2.0	3.5	5.0	4.1	2.2	2.7
Supervision	0	0	0	0	0	0	3.4	3.3	0	0	0	1.2	1.0	.4	.5
Administration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	1.9	2.4	2.8	2.6	4.1	4.1	8.6	8.3	1.5	2.0	3.5	6.2	5.1	2.6	3.3

5.4 Average Component Cost/Total Cost

Averaged incremental component costs for each city, province and region are given in Table 15.

Comments

1. As upgraded building envelopes become standard practice, the mechanical system makes up a greater portion of the incremental costs. The averages for Saskatchewan and Manitoba reflect this with 65% of the incremental cost of Saskatchewan houses being attributed to the mechanical system.

Table 15: AVERAGE COMPONENT COST OF ACTUAL R-2000 HOUSE AS A PERCENTAGE OF TOTAL INCREMENTAL COSTS

City (# of Homes	Category		High (%)	Low (%)	Average (%)	Province		Average (%)	Region		Average (%)
Edmonton (7)	Envelope	(E)	60.2	36.9	**53.7**						
	Mechanical	(M)	49.8	28.4	**38.7**						
	Other	(O)	18.9	2.8	**7.6**		E	**49.6**			
						Alberta (12)	M	**43.5**			
Calgary/Red Deer	Envelope	(E)	55.2	30.9	**45.5**		O	**7.0**			
(5)	Mechanical	(M)	57.1	39.2	**48.3**						
	Other	(O)	6.8	5.6	**6.3**						
Regina (3)	Envelope	(E)	40.4	36.2	**38.9**						
	Mechanical	(M)	61.0	57.2	**58.5**						
	Other	(O)	2.8	2.4	**2.6**		E	**30.1**		E	**41.5**
						Saskatchewan	M	**64.6**	Prairies	M	**53.1**
Saskatoon	Envelope	(E)	40.1	6.9	**21.3**	(7)	O	**4.5**	(26)	O	**3.6**
	Mechanical	(M)	89.0	51.6	**70.7**						
	Other	(O)	8.4	4.1	**6.3**						
Winnipeg (6)	Envelope	(E)	70.3	25.8	**44.9**		E	**44.9**			
	Mechanical	(M)	69.1	27.1	**51.3**	Manitoba (6)	M	**51.3**			
	Other	(O)	6.2	2.1	**3.8**		O	**3.8**			

6.0 ESTIMATED ANNUAL R-2000 INCREMENTAL SAVINGS

Section 6.0 presents information that will give the reader an idea of the potential savings that can be realized using different R-2000 construction techniques. The reported figures were generated using the HOT-2000 computer program and are, therefore, strictly estimates.

6.1 Estimated Annual Energy Savings

Each of the R-2000 upgrades contributed to the overall reduction in energy consumption of the R-2000 house. The reduction in energy consumption associated with each component was estimated using the HOT-2000 program and is presented in Tables 16a and 16b. The energy savings of each component represents the HOT-2000 estimated energy consumption differential between the Conventional house and the Actual R-2000 house.

Comments

1. The *Air Sealing/Ventilation* component represents the energy savings resulting from a combination of the reduced air leakage through the building envelope due to the continuous air barrier, and the heat recovery of the mechanical ventilation system. The heat contributed to the house by the ventilation system electrical motors was also accounted for in the component. It was not possible to separate the effects of these components.

2. The ventilation rate of the Conventional house was based on 0.5 air changes per hour (ACH) which has typically been accepted as the air change rate required to maintain adequate indoor air quality. The ventilation rate of the Actual R-2000 house was based on 0.05 ACH of natural ventilation and a continuous mechanical ventilation rate calculated by the HOT-2000 program. The combined ventilation rate for the Actual R-2000 house was typically between 0.4 and 0.5 ACH.

3. The *Usable Solar Gains* component represents the passive solar gain through the windows that can be used to offset the space heating load. As increased insulation levels reduce heat loss through the building envelope, the amount of available solar energy exceeds the amount that can be utilized by the house to maintain a comfortable indoor temperature. The negative *Usable Solar Gains* figures on the table represent the unused

solar potential ie. there is a reduction in the amount of *Usable Solar Gains* for the R-2000 house.

4. The *HRV ELECTRICAL CONSUMPTION* is based on continuous operation of the heat recovery ventilator.

6.2 Estimated Annual Cost Savings

The energy savings reported in Tables 16a and 16b were converted to cost savings using 1987 billing rates for each of the centers. These cost savings are given in Tables 17a and 17b.

Anomalies in the data that require further explanation are as follows:

1. A negative savings on this table indicates that the energy cost of the component was greater for the Actual R-2000 house than for the Conventional house.

2. Although there was a decrease in usable solar gains when the Conventional house was upgraded to the Actual R-2000 house, the Actual R-2000 houses that switched from gas to electricity showed an annual energy savings because the high cost of electricity inflated the value of the usable solar energy in these houses.

Comments

1. The *Furnace Efficiency Factor (FEF)* was determined using the energy estimates predicted by the HOT-2000 program. The FEF was calculated by dividing the difference between the Auxiliary Energy Required for heating the Conventional and Actual R-2000 houses by the difference between their Annual Energy Consumption. This calculation takes into account the efficiency of the space heating appliances and the ventilation equipment electrical contributions in both the Conventional and Actual R-2000 house.

2. The FEF abbreviation G/E for House #7a, and House #14a to #15b, denotes a change from the use of natural gas heating equipment in the Conventional house to electric equipment in the Actual R-2000 house.

3. It was necessary to specify the electrical billing rates for Red Deer and Winnipeg with an equation (EQN). For comparison purposes, however, the rates in both centers can be considered to be approximately 4.5 cents per kilowatt hour, or $12.50 per gigajoule.

4. The *NET ANNUAL COST SAVINGS* for House #7a was negative. This house was upgraded to electric heating appliances and, even with the R-2000 upgrades, Alberta's high cost of electricity relative to natural gas resulted in energy costs that were higher for the Actual R-2000 house than the Conventional house.

5. The *NET ANNUAL COST SAVINGS* for House #14a, #14b, #15a and #15b remained positive even though the builders changed from natural gas to electricity. This is due to the fact that natural gas prices in Manitoba are almost twice as high as in Alberta, but electrical rates are similar.

Table 16a: ESTIMATED ANNUAL ENERGY SAVINGS OF R-2000 UPGRADES (MJ)

	Alberta												
	Edmonton							Red Deer		Calgary			
Builder/House Number	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Component													
1. Slab/Foundation	0	6763	0	6720	6414	0	9820	0	0	0	0	3178	6393
2. Basement Walls	7550	4922	8050	6805	5824	6182	8190	876	0	6594	5982	3658	9094
3. Exterior Walls	0	9812	6984	4864	7974	3998	6124	0	0	8197	6235	1951	3830
4. Attic/Roof	0	3484	3376	1804	2057	1319	2288	0	2669	3281	3482	2133	3017
5. Windows	17030	2912	0	9337	12776	15150	13153	7617	6457	0	0	0	5180
6. Air Sealing/Ventilation													
- air sealing/HRV efficiency	*61332*	*58996*	*58057*	*38022*	*56727*	*39704*	*70372*	*38180*	*26010*	*57287*	*46874*	*20105*	*36841*
- Net HRV electrical contribution	*1506*	*1508*	*2318*	*1814*	*1506*	*1508*	*1791*	*1520*	*1520*	*1502*	*1502*	*1502*	*2290*
Total Gain	62838	60503	60374	39836	58235	40711	72163	39701	29531	58789	48376	21607	39131
7. Usable Solar Gains	-11552	-7818	-7712	-10172	-11620	-11807	-10639	-6533	-5091	-4058	-5629	-3991	-13826
SPACE HEATING SAVINGS	75866	80577	71072	59193	81620	55554	101100	41661	33565	72803	58445	28536	52820
WATER HEATING SAVINGS	8534	8548	8548	8531	8531	8531	8531	8531	8531	8548	8548	8548	8548
HRV ELECTRICAL CONSUMPTION	-3013	-3016	-4637	-3627	-3016	-3016	-3583	-3042	-3042	-3005	-3005	-3005	-4581

Table 17a: ESTIMATED ANNUAL COST SAVINGS ($) OF R-2000 UPGRADES BASED ON 1987 BILLING RATES

Furnace Efficiency Factor	.4605	.8000	.8000	.8000	.8000	.8000	.8000	.5196	.5026	.5234	.5297	G/E	.5709
Natural Gas Billing Rate ($/GJ)	2.6629	2.6629	2.6629	2.6629	2.6629	2.6629	2.6629	2.5979	2.5979	2.7413	2.7413	2.7413	2.7413
Electricity Billing Rate ($/kWh)	.0413	.0413	.0413	.0413	.0413	.0413	.0413	EQN	EQN	.0485	.0485	.0485	.0485
Electricity Billing Rate ($/GJ)	11.47	11.47	11.47	11.47	11.47	11.47	11.47	EQN	EQN	13.47	13.47	13.47	13.47
Component													
1. Slab/Foundation	0	22.51	0	22.37	21.35	0	32.69	0	0	0	0	-73.72	30.70
2. Basement Walls	41.94	16.38	26.79	22.65	19.38	20.58	27.26	4.38	0	34.54	30.96	-39.19	43.67
3. Exterior Walls	0	32.66	23.25	16.19	26.41	13.31	20.39	0	0	42.93	32.27	-42.33	18.39
4. Attic/Roof	0	11.60	11.24	6.00	6.85	4.39	7.62	0	13.80	17.18	18.02	-32.07	14.49
5. Windows	94.38	9.69	0	31.08	42.53	50.43	43.78	38.08	33.38	0	0	0	24.88
6. Air Sealing/Ventilation	348.24	201.39	200.96	132.60	193.84	135.51	240.20	198.49	152.65	307.91	250.37	-38.10	187.91
7. Usable Solar Gains	-64.02	-26.02	-25.67	-33.86	-38.68	-39.30	-35.41	-32.66	-26.32	-21.25	-29.14	92.43	-66.39
SPACE HEATING SAVINGS	420.44	268.21	236.57	197.03	271.68	184.92	336.52	208.29	173.51	381.31	302.49	-132.98	253.65
WATER HEATING SAVINGS	22.73	22.76	22.76	22.72	22.72	22.72	22.72	22.16	22.16	23.43	23.43	-126.66	23.43
HRV OPERATION COSTS	-34.57	-34.60	-53.20	-41.61	-34.60	-34.60	-41.10	41.00	41.00	-40.48	-40.49	40.48	-61.72
ESTIMATED NET ANNUAL SAVINGS	477.73	325.57	312.53	261.36	329.00	242.23	400.34	189.46	154.67	445.23	366.40	-300.12	338.79

Table 16b: ESTIMATED ANNUAL ENERGY SAVINGS OF R-2000 UPGRADES (MJ)

	Saskatchewan								Manitoba						
	Regina				Saskatoon				Winnipeg						
Builder/House Number	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
Component															
1. Slab/Foundation	0	0	0	0	0	0	5659	0	0	5250	0	0	0	6262	0
2. Basement Walls	153025	91720	19770	31924	0	0	0	0	0	7592	9119	5686	4750	8707	7005
3. Exterior Walls	11055	0	0	0	0	0	3840	4956	0	4574	0	0	0	7869	4419
4. Attic/Roof	4432	0	0	0	0	0	1677	2710	0	1858	1031	0	760	2078	2365
5. Windows	0	11284	4806	8863	0	0	0	0	0	0	0	0	0	0	0
6. Air Sealing/Ventilation															
- air sealing/HRV efficiency	*50155*	*58310*	*40631*	*52237*	*27983*	*63884*	*36692*	*44175*	*43708*	*37196*	*55895*	*33934*	*41542*	*43097*	*38993*
- Net HRV electrical contribution	*1430*	*1434*	*1430*	*1430*	*1450*	*1450*	*1453*	*1453*	*1449*	*1449*	*1709*	*1417*	*1709*	*2038*	*2038*
Total Gain	51585	59744	42061	53667	29433	64334	38145	45628	45156	38645	57604	35351	43251	45135	42031
7. Usable Solar Gains	-10080	-11355	-4494	-7066	-1782	-6844	-3259	-3115	-1707	-2534	-4046	-986	-3522	-4864	-4740
SPACE HEATING SAVINGS	210017	151393	62143	87388	27651	57490	46062	50179	43449	55384	63708	40051	45238	65188	51081
WATER HEATING SAVINGS	8534	8531	8534	8548	8548	8548	19672	19672	0	0	19682	19682	19682	19682	19682
HRV ELECTRICAL CONSUMPTION	-2861	-2868	-2861	-2861	-2899	-2899	-2906	-2906	-2896	-2896	-3417	-2835	-3417	-4077	-4077

Table 17b: ESTIMATED ANNUAL COST SAVINGS ($) OF R-2000 UPGRADES BASED ON 1987 BILLING RATES

Furnace Efficiency Factor	.5974	.5498	.4981	.5079	.4498	.4734	.5457	.5183	.5314	1	.5311	G/E	G/E	G/E	G/E
Natural Gas Billing Rate ($/GJ)	3.4173	3.4173	3.4173	3.4173	3.4173	3.4173	3.4173	3.4173	5.2685	5.2685	5.2685	5.2685	5.2685	5.2685	5.2685
Electricity Billing Rate ($/kWh)	.0603	.0603	.0603	.0603	.0603	.0603	.0603	.0603	EQN	EQN	EQN	EQN	EQN	EQN	EQN
Electricity Billing Rate ($/GJ)	16.75	16.75	16.75	16.75	16.75	16.75	16.75	16.75	EQN	EQN	EQN	EQN	EQN	EQN	EQN
Component															
1. Slab/Foundation	0	0	0	0	0	0	35.44	0	0	62.43	0	-67.83	-52.81	17.10	-69.91
2. Basement Walls	875.30	570.07	135.63	214.81	0	0	0	0	0	88.96	90.46	15.73	12.52	45.23	21.81
3. Exterior Walls	63.23	0	0	0	0	0	24.05	32.68	0	54.78	0	-53.77	-88.70	-16.68	1.23
4. Attic/Roof	25.35	0	0	0	0	0	10.50	17.87	0	24.01	10.22	-30.00	-14.61	-10.24	-9.65
5. Windows	0	70.14	32.97	59.64	0	0	0	0	0	0	0	0	0	0	-18.35
6. Air Sealing/Ventilation	295.07	371.33	288.55	361.12	223.61	464.45	238.87	300.84	514.48	440.72	571.42	219.47	291.64	282.42	271.38
7. Usable Solar Gains	-57.66	-70.58	-30.83	-47.55	-13.54	-49.41	-20.41	-20.54	-33.43	-25.75	-40.13	31.50	36.37	11.34	7.54
SPACE HEATING SAVINGS	1201.30	940.96	426.31	588.02	210.07	415.04	288.46	330.84	481.05	645.14	631.97	115.09	184.40	329.17	204.05
WATER HEATING SAVINGS	29.16	29.15	29.16	29.21	29.21	29.21	-178.75	-178.75	0	0	-9.15	-11.07	-11.07	-11.07	-11.07
HRV OPERATION COSTS	-47.92	-48.04	-47.92	-47.92	-48.56	-48.56	-48.68	-48.68	-29.84	-29.84	-35.75	35.07	41.67	49.14	49.14
ESTIMATED NET ANNUAL SAVINGS	1278.38	1018.15	503.40	665.15	287.84	492.81	158.38	200.77	510.89	674.99	658.56	68.95	131.66	268.95	143.84

6.3 Estimated Cost of Changing Fuel Type

The estimated energy costs in converting from natural gas to electricity were calculated for Houses #7a, #14a, #14b, #15a and #15b and are presented in Tables #18a and #18b. These tables also give the estimated cost of heating the same R-2000 houses with medium efficiency gas-fired equipment and provide the basis for a comparison of the actual savings with electricity to the potential savings with natural gas.

Comments

1. In Alberta, the R-2000 upgrades in House #7a could have reduced the estimated energy costs by $142 if medium efficiency natural gas, instead of electric, heating equipment had been installed. Instead, the estimated heating costs for the Actual R-2000 house using electrical heating equipment were $300 greater than for the Conventional house. The net difference between electrical and gas heating costs were $442.

2. In Manitoba, where natural gas prices are higher, net savings were realized when the builders converted from natural gas to electricity. The potential savings with natural gas, however, would be greater. For example, compared to the Conventional house, the estimated energy costs for House #14a were reduced by $69 when electric appliances were used. These costs could have been reduced by $466 had gas appliances been installed.

3. The net *Estimated Compared Savings* figures show the difference between estimates of actual energy consumption potential energy consumption. They represent a lost savings potential. In Alberta and Manitoba, the net additional savings would quickly pay for the higher initial cost of the medium efficiency gas furnace.

4. Builders considering a change from natural gas to electricity should consider the different energy targets and resulting construction cost for each fuel. The HOT-2000 program provides credits for natural gas equipment to compensate for its higher initial cost. Builder #15 chose electric space and water heating for House #15a. As a result, the R-2000 energy target dropped from 99644 MJ for natural gas heating to 70747 MJ (see Table 7). In order to meet the lower energy target, the builder used a rigid fiberglass insulation on the exterior walls which added over $2400 (including jamb extensions) to the incremental costs. Builder #11, however, switched from electric to medium efficiency gas-fired water heaters. This increased the R-2000 energy target by 15,800 MJ allowing him to realize large cost savings by reducing envelope insulation levels.

Table 18a: ESTIMATED ANNUAL SAVINGS OF R-2000 UPGRADES USING ELECTRICITY VS NATURAL GAS

A. Estimated Energy Consumption (MJ) Of Conventional Vs R-2000 House

	Southern Alberta Calgary			Manitoba Winnipeg			
Builder/House Number	7a-CONV	7a-R2000		14a-CONV	14a-R2000	14b-CONV	14b-R2000
Component							
1. Slab/Foundation	12776	9598		19356	20017	14717	15266
2. Basement Walls	9840	6087		17946	11599	15021	9723
3. Exterior Walls	7522	5571		17135	17135	28918	28918
4. Attic/Roof	6667	4533		9118	9118	6832	6073
5. Windows	0	0		0	0	0	0
					6. Air Sealing/ Ventilation		
- air sealing/HRV efficiency	*31654*	*11549*		*49212*	*15277*	*52819*	*11277*
- Net HRV electrical contribution	*0*	*1502*		*0*	*1417*	*0*	*1709*
Net Gain	31654	13051		49212	16694	52819	12986
7. Usable Solar Gains (subtract)	16029	12038		13392	12406	24722	21200
TOTAL SPACE HEATING	52430	26804		99375	62157	93585	51765
WATER HEATING	38134	17161		38134	18452	38134	18452
HRV ELECTRICAL CONSUMPTION	0	3005		0	2835	0	3417

B. Estimated Component Energy Cost ($) Based On 1987 Billing Rates

Builder/House Number	7a-STD	ELEC	GAS	14a-ST	ELEC	GAS	14b-ST	ELEC	GAS
Furnace Efficiency Factor	.63	1	.80	.63	1	.80	.63	1	.80
Natural Gas Billing Rate ($/GJ)	2.7413	2.7413	2.7413	5.2685	5.2685	5.2685	5.2685	5.2685	5.2685
Electricity Billing Rate ($/kWh)	.0485	.0485	.0485	EQN	EQN	EQN	EQN	EQN	EQN
Component									
1. Slab/Foundation	55.59	129.31	32.89	161.87	229.70	131.82	123.08	175.89	100.54
2. Basement Walls	42.82	82.01	20.86	150.07	134.35	76.38	125.62	113.10	64.03
3. Exterior Walls	32.73	75.06	19.09	143.30	197.07	112.85	241.83	330.53	190.44
4. Attic/Roof	29.01	61.07	15.53	76.25	106.25	60.05	57.14	71.75	39.99
5. Windows	0	0	0	0	0	0	0	0	0
6. Air Sealing/ Ventilation	137.74	175.83	44.72	411.54	192.07	109.94	441.71	150.06	85.52
7. Usable Solar Gains (subtract)	69.74	162.17	41.25	111.99	143.49	81.70	206.74	243.11	139.62
SPACE HEATING COSTS	228.14	361.11	91.85	831.04	715.95	409.35	782.62	598.22	340.90
WATER HEATING COSTS	104.54	231.20	58.80	200.91	211.98	121.52	200.91	211.98	121.52
HRV OPERATION COSTS	0	40.48	40.48	0	35.07	35.07	0	41.67	41.67
ESTIMATED NET ANNUAL COSTS	332.68	632.80	191.14	1031.95	963.00	565.94	983.53	851.87	504.09

C. Estimated Compared Savings

	ELEC	GAS	7a-NET	ELEC	GAS	14a-NET	ELEC	GAS	14b-NET
Space Heating	-132.98	136.29	269.27	115.09	421.69	306.60	184.40	441.72	257.32
Water Heating	-126.66	45.73	172.39	-11.07	79.39	90.46	-11.07	79.39	90.46
HRV Operation	-40.48	-40.48	0	-35.07	-35.07	0	-41.67	-41.67	0
Estimated Savings Using Electricity or Gas	-300.12	141.54	441.66	68.95	466.01	397.06	131.66	479.44	347.78

Table 18b: ESTIMATED ANNUAL SAVINGS OF R-2000 UPGRADES USING ELECTRICITY VS NATURAL GAS

A. Estimated Energy Consumption (MJ) Of Conventional Vs R-2000 House

Builder/House Number	Manitoba Winnipeg 15a-CONV	15a-R2000		15b-CONV	15b-R2000
Component					
1. Slab/Foundation	17159	10896		20100	20749
2. Basement Walls	16198	7705		20889	13235
3. Exterior Walls	34692	26822		15471	11051
4. Attic/Roof	10395	8317		9563	7650
5. Windows	0	0		14226	11860
6. Air Sealing/ Ventilation					
- air sealing/HRV efficiency	*60613*	*17516*		*52479*	*12486*
- Net HRV electrical contribution	*0*	*2038*		*0*	*2038*
Net Gain	60613	19554		52479	14524
7. Usable Solar Gains (subtract)	21407	16543		19654	14913
TOTAL SPACE HEATING	117649	56751		113073	64156
WATER HEATING	38134	18452		38134	18452
HRV ELECTRICAL CONSUMPTION	0	4077		0	4077

B. Estimated Component Energy Cost ($) Based On 1987 Billing Rates

Builder/House Number	15a-ST	ELEC	GAS	15b-ST	ELEC	GAS
Furnace Efficiency Factor	.63	1	.80	.63	1	.80
Natural Gas Billing Rate ($/GJ)	5.2685	5.2685	5.2685	5.2685	5.2685	5.2685
Electricity Billing Rate ($/kWh)	EQN	EQN	EQN	EQN	EQN	EQN
Component						
1. Slab/Foundation	143.49	126.39	71.76	168.09	238.00	136.64
2. Basement Walls	135.46	90.24	50.74	174.69	152.88	87.16
3. Exterior Walls	290.12	306.80	176.64	129.38	128.14	72.78
4. Attic/Roof	86.93	97.17	54.77	79.97	89.62	50.38
5. Windows	0	0	0	118.96	137.31	78.11
6. Air Sealing/ Ventilation	506.89	224.47	128.78	438.86	167.49	95.65
7. Usable Solar Gains (subtract)	179.02	190.36	108.95	164.36	171.90	98.21
SPACE HEATING COSTS	983.87	654.70	373.74	945.59	741.54	422.50
WATER HEATING COSTS	200.91	211.98	121.52	200.91	211.98	121.52
HRV OPERATION COSTS	0	49.14	49.14	0	49.14	49.14
ESTIMATED NET ANNUAL COSTS	1184.78	915.82	544.40	1146.50	1002.67	593.17

C. Estimated Compared Savings

	ELEC	GAS	15a-NET	ELEC	GAS	15b-NET
Space Heating	329.17	610.13	280.96	204.05	523.09	319.04
Water Heating	-11.07	79.39	90.46	-11.07	79.39	90.46
HRV Operation	-49.14	-49.14	0	-49.14	-49.14	0
Estimated Savings Using Electricity	268.95	640.38	371.42	143.84	553.34	409.50

7.0 ECONOMIC ANALYSIS OF R-2000 HOUSES

An economic analysis of the Actual R-2000 house and the Optimized R-2000 house compared to the Conventional house was carried out using the HOT-2000 program. Information used in carrying out the analysis is presented in Tables 19a and 19b along with the simple payback period, the discounted payback period and the years to positive cash flow. Typically in residential housing, a simple payback period of less than 5 years is considered acceptable while a period greater than 10 years is not considered acceptable. Acceptance of payback periods between 5 and 10 years will depend on the individual.

An explanation of the terms in these tables is given below.

1. The *Selling Price* for each house included the construction cost, plus a $40,000 land cost, plus builder overhead and profit at 20% of the construction cost. The municipal tax rate was assumed to be 1.5% of the selling price.

2. A *Downpayment* of 10% was used for these calculations. Although downpayments as high as 30% may be more realistic for second-time homebuyers, it was determined using the HOT-2000 program that a higher downpayment does not significantly change the payback period for energy conservation components.

3. *Annual Energy Costs* were determined using energy consumption data from the HOT-2000 program's *R-2000 Home Program Energy Consumption Summary Report* and the 1987 billing rates in Table 18. The fuel escalation rate and the annual inflation rate were each assumed to be 5%.

4. The *Simple Payback Period* was calculated as the selling price differential between the Conventional house and the energy conserving house (either Actual R-2000 or Optimized R-2000) divided by the annual energy cost differential. This calculation does not include fuel price escalation or the accumulated interest on the price differential. The price differential between the two houses is the incremental cost of upgrades that have resulted in lowering the annual energy costs.

5. The *Discounted Payback Period* was calculated in the same manner as the simple payback period but includes fuel price escalation and the mortgage interest on the price differential. The mortgage rate was assumed to be 10% and the annual savings interest rate to be 7%. The mortgage rate used may seem low compared to prevailing rates, but these are expected to come down over the long term period covered by this payback analysis. The use of a relatively low mortgage rate is not considered

detrimental to the analysis. It tends to yield somewhat shorter discounted payback periods, but these are still higher than the simple payback periods.

6. The *Years To Positive Cash Flow* identifies the year when the total monthly Principal, Interest, Taxes and Energy (P.I.T.E.) costs for the energy conserving house are less than those for the Conventional house. It provides an indication of when the total monthly cash outlay for the energy conserving home will be less than the Conventional home. The mortgage term was assumed to the 5 years and the amortization period to be 25 years.

Comments

1. Discrepancies between the annual energy savings differential of the Conventional and Actual R-2000 houses in Table 19, and the *Estimated Net Annual Savings* reported in Table 17, are due to differences in the methods used for calculating total and component energy losses in the HOT-2000 program.

2. House #7a had no payback (No Pay) because the annual energy costs of the Conventional house were lower than the Actual and Optimized R-2000 houses. Electric appliances were used in these houses and, even with the energy conservation upgrades, the high cost of electricity resulted in higher energy costs for these R-2000 houses. This would not have occurred if gas appliances had been installed.

3. Based on the simple payback method, only three Actual R-2000 houses had a payback period of less than 10 years with one of these having a payback period of less than 5 years. Two of these house were in Regina where the builder's Conventional houses were not insulated in the basement. The short payback period for installing basement insulation brought the overall payback period below 10 years. The third house was in Manitoba where the builder's Actual R-2000 house was optimized and gas prices are higher.

   When the Actual R-2000 houses were optimized, only one additional house had a simple payback period of less than 10 years.

4. Based on the discounted payback period, one Actual R-2000 house and one additional Optimized R-2000 house had a payback period of less than 10 years.

Table 19a: ECONOMIC ANALYSIS OF ACTUAL R2000 HOUSE VS CONVENTIONAL HOUSE

	Northern Alberta							Southern Alberta					
	Edmonton							Red Deer		Calgary			
A. Conventional House	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
CONVENTIONAL HOUSE COST	103000	110340	92700	52844	86360	90100	127200	67000	69400	105847	81540	36200	69000
SELLING PRICE	163600	172408	151240	103413	143632	148120	192640	120400	123280	167016	137848	83440	122800
DOWNPAYMENT	16360	17241	15124	10341	14363	14812	19264	12040	12328	16702	13785	8344	12280
ANNUAL ENERGY COSTS	754	561	523	405	555	434	669	442	402	724	584	278	441
PROPERTY TAXES	2454	2586	2269	1551	2154	2222	2890	1806	1849	2505	2068	1252	1842
B. R2000 House													
R2000 HOUSE COST	110024	117007	97455	57380	90972	95078	133547	70550	73269	112229	87139	38819	74447
SELLING PRICE	172028	180408	156946	108856	149166	154094	200256	124660	127923	174675	144567	86583	129336
DOWN PAYMENT	17203	18041	15695	10886	14917	15409	20026	12466	12792	17467	14457	8658	12934
ANNUAL ENERGY COSTS	354	313	332	241	304	270	361	261	255	369	308	633	242
PROPERTY TAXES	2580	2706	2354	1633	2237	2311	3004	1870	1919	2620	2169	1299	1940
SIMPLE PAYBACK	21	>25	>25	>25	>25	>25	>25	>25	>25	>25	>25	No Pay	>25
DISCOUNTED PAYBACK PERIOD	>25	>25	>25	>25	>25	>25	>25	>25	>25	>25	>25		>25
YEARS TO POSITIVE CASH FLOW	>25	>25	>25	>25	>25	>25	>25	>25	>25	>25	>25		>25
INCREMENTAL COSTS	7024	6667	4755	4536	4612	4978	6347	3550	3869	6382	5599	2619	5447
% OF SELLING PRICE	4.1	3.7	3.0	4.2	3.1	3.2	3.2	2.8	3.0	3.7	3.9	3.0	4.2
C. Optimized House													
OPTIMIZED HOUSE COST	108964	114707	97234	55980	89579	93833	131083	70131	72466	109953	85448	37968	72482
SELLING PRICE	170756	177648	156681	107176	147495	152600	197300	124157	126959	171943	142538	85562	126978
DOWNPAYMENT	17076	17765	15668	10718	14749	15260	19730	12416	12696	17194	14254	8556	12698
ANNUAL ENERGY COSTS	374	345	336	286	363	286	396	277	256	391	332	539	277
PROPERTY TAXES	2561	2665	2350	1608	2212	2289	2959	1862	1904	2579	2138	1283	1905
SIMPLE PAYBACK	19	24	>25	>25	20	>25	17	23	25	15	19	No Pay	>25
DISCOUNTED PAYBACK PERIOD	>25	>25	>25	>25	21	>25	>25	>25	>25	>25	>25		>25
YEARS TO POSITIVE CASH FLOW	18	>25	>25	>25	>25	>25	>25	>25	>25	13	21		>25
INCREMENTAL COSTS	5964	4367	4534	3136	3219	3733	3883	3131	3066	4106	3908	1768	3482
% OF SELLING PRICE	3.5	2.5	2.9	2.9	2.2	2.4	2.0	2.5	2.4	2.4	2.7	2.1	2.7
D. Prescriptive Standards													
SELLING PRICE	171953	179376	156828	107715	148271	152540	198820	124437	127211	172065	142708	86714	126978
INCREMENTAL COSTS	6961	5807	4657	3585	3866	3683	5150	3364	3276	4207	4050	2728	3482
% OF SELLING PRICE	4.0	3.2	3.0	3.3	2.6	2.4	2.6	2.7	2.6	2.4	2.8	3.1	2.7

Table 19b: ECONOMIC ANALYSIS OF ACTUAL R2000 HOUSE VS CONVENTIONAL HOUSE

	Saskatchewan								Manitoba						
	Regina		Saskatoon						Winnipeg						
A. Conventional House	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
CONVENTIONAL HOUSE COST	112900	102800	72900	81200	64400	140600	53890	91830	91000	115000	110400	61200	63860	105000	97600
SELLING PRICE	175480	163360	127480	137440	117280	208720	104668	150196	149200	178000	172480	113440	116632	166000	157120
DOWNPAYMENT	17548	16336	12748	13744	11728	20872	10467	15020	14920	17800	17248	11344	11663	16600	15712
ANNUAL ENERGY COSTS	1566	1339	748	979	469	781	550	669	1391	1191	1178	901	918	1110	953
PROPERTY TAXES	2632	2450	1912	2062	1759	3131	1570	2253	2238	2670	2587	1702	1749	2490	2357
B. R2000 House															
R2000 HOUSE COST	120996	109180	78318	86933	68025	144225	56801	94836	98309	120535	112515	63683	66890	111827	103081
SELLING PRICE	185195	171016	133982	144320	121630	213070	108161	153803	157971	184642	175018	116420	120268	174192	163697
DOWN PAYMENT	18520	17102	13398	14432	12163	21307	10816	15380	15797	18464	17502	11642	12027	17419	16370
ANNUAL ENERGY COSTS	400	435	362	424	295	398	497	572	550	653	613	778	762	860	745
PROPERTY TAXES	2778	2565	2010	2165	1824	3196	1622	2307	2370	2770	2625	1746	1804	2613	2455
SIMPLE PAYBACK	9	8	17	12	>25	11	>25	>25	10	12	4	24	23	>25	>25
DISCOUNTED PAYBACK PERIOD	11	11	>25	19	>25	16	>25	>25	16	21	5	>25	>25	>25	>25
YEARS TO POSITIVE CASH FLOW	1	1	>25	8	>25	5	>25	>25	5	9	1	>25	>25	>25	>25
INCREMENTAL COSTS	8096	6380	5418	5733	3625	3625	2911	3006	7309	5535	2115	2483	3030	6827	5481
% OF SELLING PRICE	4.4	3.7	4.0	4.0	3.0	1.7	2.7	2.0	4.6	3.0	1.2	2.1	2.5	3.9	3.3
C. Optimized House															
OPTIMIZED HOUSE COST	117784	108177	77108	85644	67025	143225	56440	94430	98309	119108	112515	64009	66821	110414	100895
SELLING PRICE	181341	169812	132530	142773	120430	211870	107728	153316	157971	182930	175018	116811	120185	172497	161074
DOWNPAYMENT	18134	16981	13253	14277	12043	21187	10773	15332	15797	18293	17502	11681	12019	17250	16107
ANNUAL ENERGY COSTS	458	500	399	449	314	431	344	404	551	770	516	720	769	852	773
PROPERTY TAXES	2720	2547	1988	2142	1806	3178	1616	2300	2370	2744	2625	1752	1803	2587	2416
SIMPLE PAYBACK	5	8	14	10	20	9	15	12	10	12	4	19	24	25	22
DISCOUNTED PAYBACK PERIOD	8	11	24	14	>25	12	23	16	15	19	5	>25	>25	>25	>25
YEARS TO POSITIVE CASH FLOW	1	1	12	3	18	1	11	5	5	8	1	21	>25	>25	>25
INCREMENTAL COSTS	4884	5377	4208	4444	2625	2625	2550	2600	7309	4108	2115	2809	2961	5414	3295
% OF SELLING PRICE	2.7	3.2	3.2	3.1	2.2	1.2	2.4	1.7	4.6	2.2	1.2	2.4	2.5	3.1	2.0
D. Prescriptive Standards															
SELLING PRICE	181952	169156	133122	143668	120612	212019	108435	154235	158231	183086	175092	116870	120268	172163	161488
INCREMENTAL COSTS	5397	4830	4702	5190	2777	2749	3139	3366	7526	4228	2177	2858	3030	5136	3640
% OF SELLING PRICE	3.0	2.9	3.5	3.6	2.3	1.3	2.9	2.2	4.8	2.3	1.2	2.4	2.5	3.0	2.3

5. The size of the house is an important factor in determining the payback period. For example, the incremental costs of House #10a and #10b were identical but the payback periods for the larger house are about one-half as long as those for the smaller house.

6. The houses constructed by Builders #14 and #15 had simple payback periods greater than 20 years because the builders installed electric appliances. The payback periods were recalculated assuming a medium efficient gas furnace had been installed. As a result, the simple payback periods were reduced to 7 years for House #14a, to 9 years for House #14b, to 13 years for House #15a and 9 years for House #15b.

7.1 Average Incremental Cost/Selling Price

Tables 19a and 19b also give the incremental costs of the Actual R-2000 and Optimized R-2000 houses as a percentage of the selling price. These figures have been averaged for each center and province and are presented in Table 20.

Comments

1. Presenting the incremental cost as a percentage of the selling price puts this figure into perspective when considering the size of the R-2000 investment compared to the overall investment in the house.

2. Table 10 presented the incremental costs as a percentage of the construction costs. As a percentage of the selling price, incremental costs are typically about 2% lower.

3. The incremental cost of the optimized R-2000 home is approximately 2% to 2.5% of the selling price as defined above.

Table 20: AVERAGE INCREMENTAL COST AS PERCENTAGE OF SELLING PRICE

A. Actual R-2000 House: Average Incremental Cost As % Of Selling Price

Edmonton (7)	4.2	3.0	3.5	Alberta (13)	3.5		
Calgary/Red Deer (6)	4.2	2.8	3.4				
Regina (4)	4.4	3.7	4.0	Saskatchewan (8)	3.2	Prairies (27)	3.1
Saskatoon (4)	3.0	1.7	2.3				
Winnipeg (6)	3.9	1.2	2.7	Manitoba (6)	2.7		

B. Optimized R-2000 House: Average Incremental Cost As % Of Selling Price

Edmonton (7)	3.5	2.0	2.6	Alberta (13)	2.6		
Calgary/Red Deer (6)	2.7	2.1	2.5				
Regina (4)	3.2	2.7	3.0	Saskatchewan (8)	2.5	Prairies (27)	2.4
Saskatoon (4)	2.4	1.2	1.9				
Winnipeg (6)	3.1	1.2	2.3	Manitoba (6)	2.3		

C. Prescriptive Standard R-2000 House: Average Incremental Cost As % Of Selling Price

Edmonton (7)	4.0	2.4	3.0	Alberta (13)	2.9		
Calgary/Red Deer (6)	3.1	2.4	2.7				
Regina (4)	3.6	2.9	3.2	Saskatchewan (8)	2.7	Prairies (27)	2.6
Saskatoon (4)	2.9	1.3	2.2				
Winnipeg (6)	3.0	1.2	2.3	Manitoba (6)	2.3		

7.2 Simple Payback of Actual R-2000 Upgrades

The simple payback of the Actual R-2000 upgrades was calculated by dividing the incremental component costs in Table 10 by the estimated annual energy component cost savings in Table 16. This information is presented in Table 21 and is useful in determining the contribution of each R-2000 component to the long payback periods seen in Table 19.

Comments

1. Each payback figure is based on the particular type of heating system used in the builder's Conventional house and Actual R-2000 house. For example, Builder #1 uses a standard furnace in his Conventional house and a high efficiency furnace in his Actual R-2000 house. The higher the efficiency of the space heating system the greater the reduction in the payback period for each building envelope component. However, the initial cost of installing the high efficiency furnace was $1200 more than installing a medium efficiency unit which results in a longer payback period for the furnace.

   Builders #2, #3 and #4 installed medium efficiency furnaces in both their Conventional and Actual R-2000 houses. With no increase in efficiency, the payback periods of the building envelope components were not reduced and, therefore, appear longer.

   Builders changing from gas-fired to electric appliances benefited from the higher efficiency electric appliances but incurred higher energy costs. The net overall effect was either no payback period (No Pay) because component energy costs were higher than the Conventional house or a longer payback period because energy savings were small.

2. Based on the simple payback figures, only the *Basement Wall* and *Air Sealing/Ventilation* components showed reasonable payback periods.

3. To determine a simple payback for the medium and high efficiency furnace upgrades, the space heating energy costs for the Actual and the Optimized R-2000 houses with the furnace upgrade and with a standard furnace were compared. The houses with the high efficiency furnaces were #1 and #8b to #10b. Maintenance costs have not been considered.

Table 21: SIMPLE PAYBACK OF ACTUAL R-2000 HOUSE COMPONENTS (years)

	Northern Alberta Edmonton							Southern Alberta Red Deer		Calgary			
Builder/House Number	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Component													
Slab/Foundation	.0	29.0	.0	20.2	7.0	.0	14.7	.0	.0	.0	.0	No Pay	8.9
Basement Walls	4.3	10.4	6.1	7.3	9.0	7.1	6.7	.0	.0	5.8	4.9	No Pay	10.4
Exterior Walls	.0	33.7	23.6	43.2	24.8	112.3	109.6	.0	.0	52.0	47.4	No Pay	26.0
Attic/Roof	.0	38.6	27.2	34.1	20.9	30.8	29.5	.0	29.4	10.9	12.6	No Pay	28.9
Windows (incl.jamb ext.)	18.5	31.0	.0	19.0	22.8	23.2	26.7	17.4	20.9	.0	.0	No Pay	28.8
Net Air Sealing/Ventilation	7.5	13.4	11.4	13.4	9.4	10.0	5.7	7.8	9.3	7.5	9.0	No Pay	9.6
Water Heating	18.5	17.6	17.6	18.5	18.5	22.0	22.0	27.1	27.1	19.2	19.2	No Pay	19.2
Space Heating (Actual R-2000)	11.2	n/a	n/a	n/a	n/a	n/a	n/a	6.8	6.9	4.5	5.5	n/a	8.2
Space Heating (Optimized R-2000)	11.1	n/a	n/a	n/a	n/a	n/a	n/a	6.3	6.9	4.5	5.5	n/a	6.9

	Saskatchewan Regina				Saskatoon				Manitoba Winnipeg						
Builder/House Number	8a	8b	9a	9b	10a	10b	11a	11b	12a	12b	13	14a	14b	15a	15b
Component															
Slab/Foundation	.0	.0	.0	.0	.0	.0	5.6	.0	.0	6.3	.0	No Pay	No Pay	34.8	No Pay
Basement Walls	2.0	2.5	8.9	6.4	.0	.0	.0	.0	.0	10.1	2.2	18.2	22.8	25.2	46.7
Exterior Walls	30.4	.0	.0	.0	.0	.0	12.8	17.9	.0	17.2	.0	No Pay	No Pay	No Pay	1076.4
Attic/Roof	19.7	.0	.0	.0	.0	.0	24.3	15.2	.0	7.3	.0	No Pay	No Pay	No Pay	No Pay
Windows (incl.jamb ext.)	.0	10.9	13.1	8.8	.0	.0	.0	.0	.0	.0	.0	No Pay	No Pay	No Pay	No Pay
Net Air Sealing/Ventilation	5.3	4.5	6.1	5.3	6.8	3.3	6.1	4.8	3.2	3.7	3.0	7.8	7.7	9.7	9.4
Water Heating	17.1	17.2	17.7	17.6	15.4	15.4	No Pay	No Pay	.0	.0	No Pay	No Pay	No Pay	No Pay	No Pay
Space Heating (Actual R-2000)	5.1	9.8	9.0	7.1	12.8	9.0	4.9	3.6	n/a	n/a	1.2	n/a	n/a	n/a	n/a
Space Heating (Optimized R-2000)	4.7	8.9	8.1	6.7	12.0	8.3	3.5	2.9	n/a	n/a	1.2	n/a	n/a	n/a	n/a

8.0 INNOVATIVE CONSTRUCTION PRACTICES

Contractors attending the R-2000 Builders' Workshop are instructed on a number of energy efficient construction techniques. These techniques are meant to be incorporated into the builders' R-2000 designs depending upon their local conditions and material availability and upon their particular building practices.

In the R-2000 houses investigated in this study, a number of innovations were reported by R-2000 builders who have integrated R-2000 concepts and techniques with their standard construction practices. The goal of these builders was to have the construction of the R-2000 house interfere as little as possible with their standard construction methods.

8.1 Alberta Builders

The R-2000 builders interviewed in Alberta showed the greatest resistance to change and as a result were the most innovative group in the Prairie Region in developing ways of achieving R-2000 concepts with standard construction practices. Two R-2000 techniques in particular were found to be too cumbersome to incorporate into their R-2000 houses. One was wrapping the windows with polyethylene to achieve a continuous air barrier and the second was recessing and wrapping the rim joist area.

Wrapping the windows with polyethylene has been replaced with techniques that seal the gap between the window jamb and the rough opening. These methods include:

1. installing round backer rod in the rough opening gap;

2. filling the gap with a polyurethane foam; and,

3. bridging the gap with a packing or duct tape.

The majority of builders have chosen the backer rod as the most effective, practical and least expensive alternative to the window wrap.

Major innovations have occurred in developing details that successfully seal and insulate the rim joist area. Figure 1 shows a standard method of achieving a continuous air barrier and a vapour retarder. Polyethylene is wrapped

around a recessed header and insulated on the outside with rigid insulation. This method was unpopular for a number of reasons.

1. The technique deviated too much from conventional building practices and usually required more care and supervision than most builders were prepared to provide.

2. Builders using cast-in-place techniques on their conventional houses had to change to framing techniques which were more expensive.

3. It was difficult and expensive to achieve high insulation levels in this area and still obey the "One-third/Two-thirds Rule" by keeping the vapour retarder towards the warm side of the insulation.

As a result, builders devised a number of techniques to overcome these inadequacies. Figure 2 shows a modification using Tyvek, a spun-bonded polyolefin housewrap, which acts as an air barrier but not a vapour retarder. When this type of product is used, the rim joist does not have to be recessed and can be wrapped to the outside. The builder then installs batt insulation and the vapour retarder to the inside in a conventional manner. Builders #4 and #5 in Alberta used this technique.

Figure 3 shows an innovation that uses the concrete foundation wall as an air barrier. This method, in addition to having all the advantages of using Tyvek, has eliminated the need to install a continuous, caulked, polyethylene air barrier in the basement. The builder installs a polyethylene vapour barrier in a conventional manner. This method was used by Builder #6 in Alberta.

Figure 4 shows an innovation that incorporates the concepts detailed in Figure 3 into a cast-in-place foundation. This method allows the builder to follow conventional construction practices through to the main floor subfloor stage. The Tyvek is installed as shown and, in conjunction with the concrete wall, forms a continuous air barrier. A conventional polyethylene vapour retarder is installed. This method has been used successfully in Edmonton where cast-in-place foundations are commonly used.

Finally, Figures 5 and 6 show a technique that eliminates the need for wrapping the rim joist area. The header joist is used as the air barrier and sealing is achieved through the use of caulking and a bituthene membrane. This method was used by Builder #3 in Edmonton.

8.2 Saskatchewan Builders

The innovations that occurred in Alberta were not seen in Saskatchewan. All of these builders wrapped the windows with polyethylene and sealed the rim joist area using R-2000 suggested techniques as described below.

1. Builder #8 used a company specializing in polyethylene air sealing techniques to seal the polyethylene between the floor joists.

2. Builder #9 installed and caulked wooden blocks between the floor joist.

3. Builder #10 installed and caulked Styrofoam blocks between the floor joist.

4. Builder #11 recessed and wrapped the rim joist with polyethylene.

8.3 Manitoba Builders

R-2000 suggested techniques were also used in Manitoba. All of the builders used a polyethylene window wrap. Builders #12 and #13 recessed and wrapped the rim joist area while Builders #14 and #15 installed and caulked rigid insulation blocks between the floor joists.

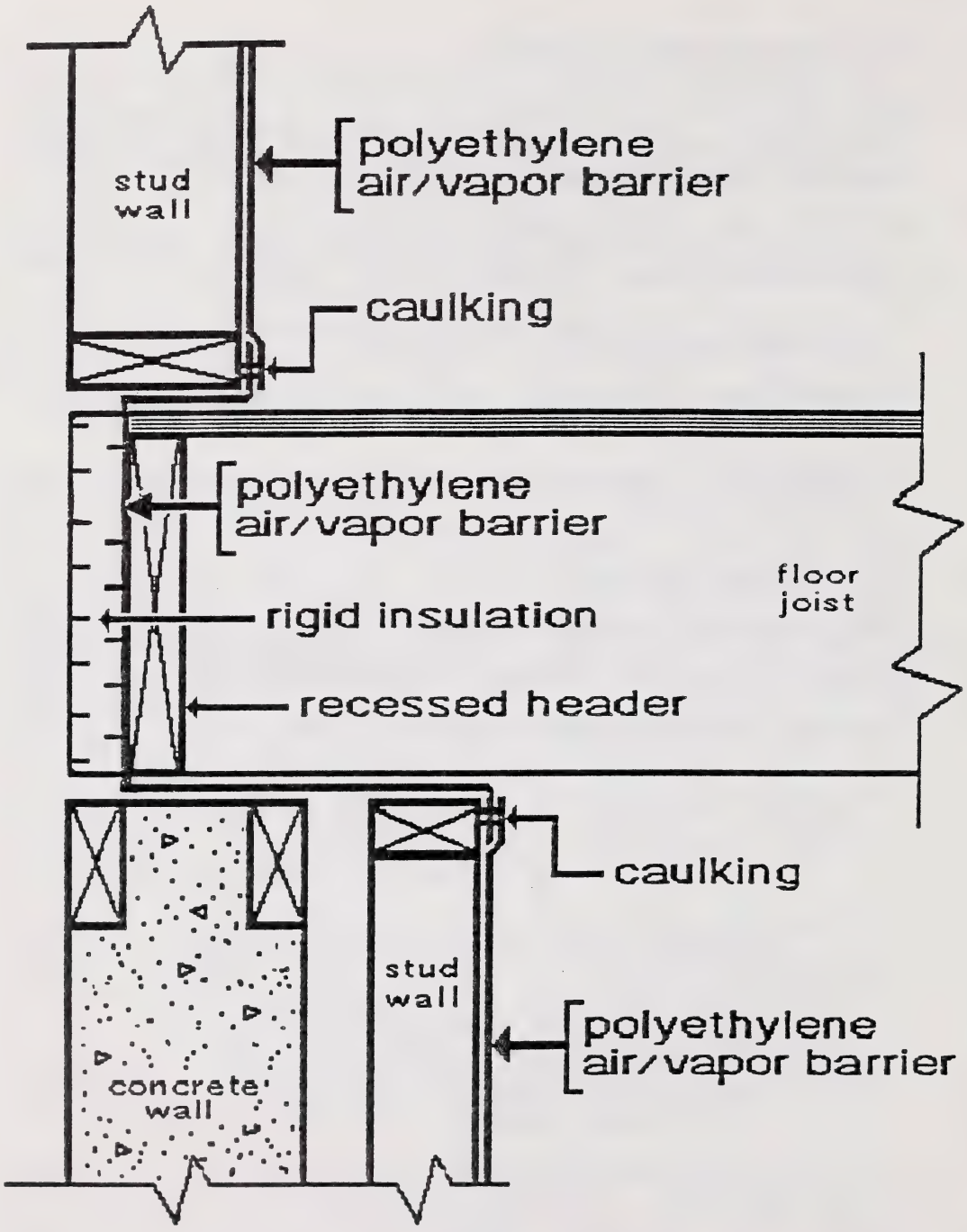

Figure 1: Standard Polyethylene Air/Vapor Barrier

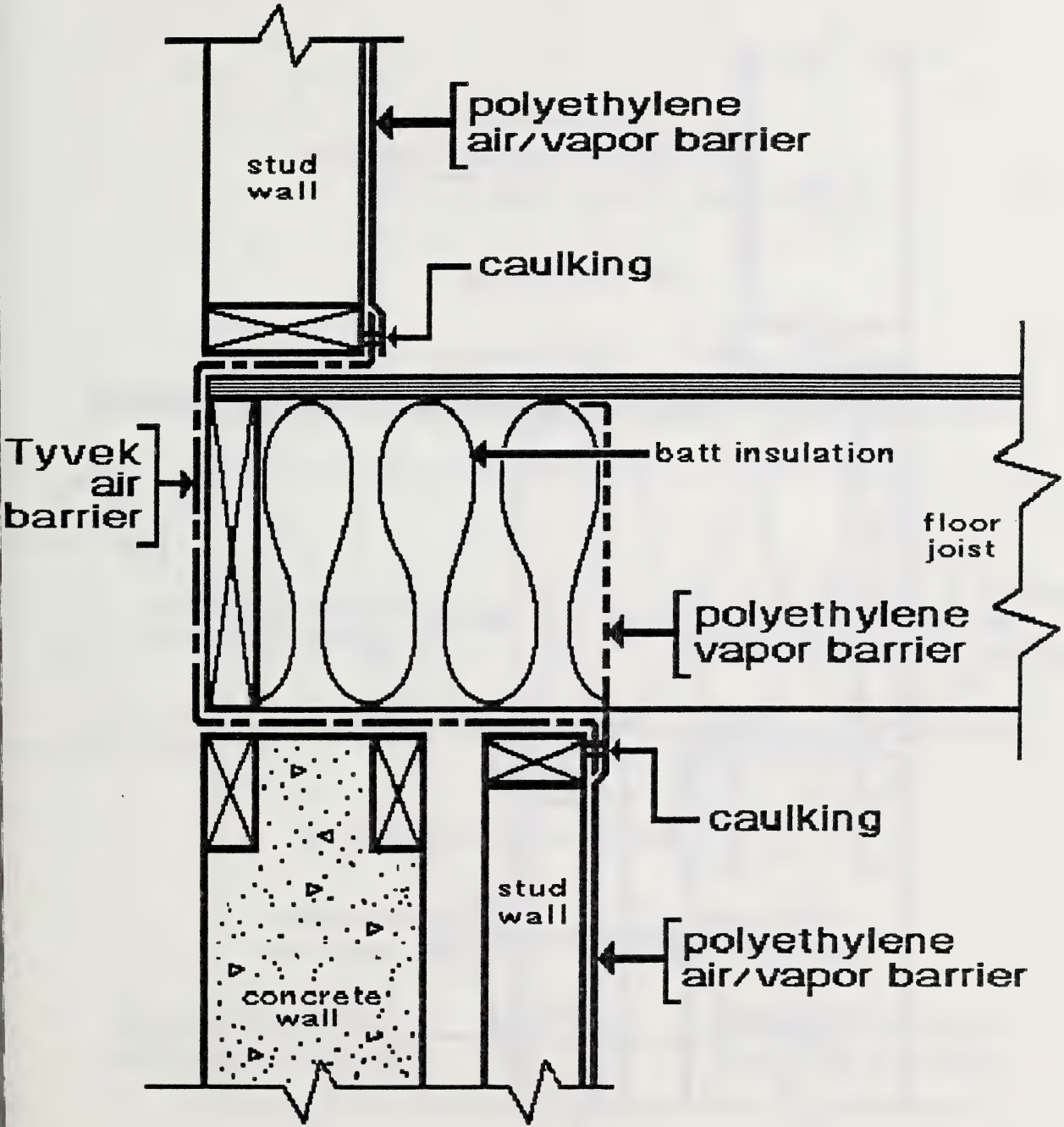

Figure 2: Modification Using Tyvek Air Barrier

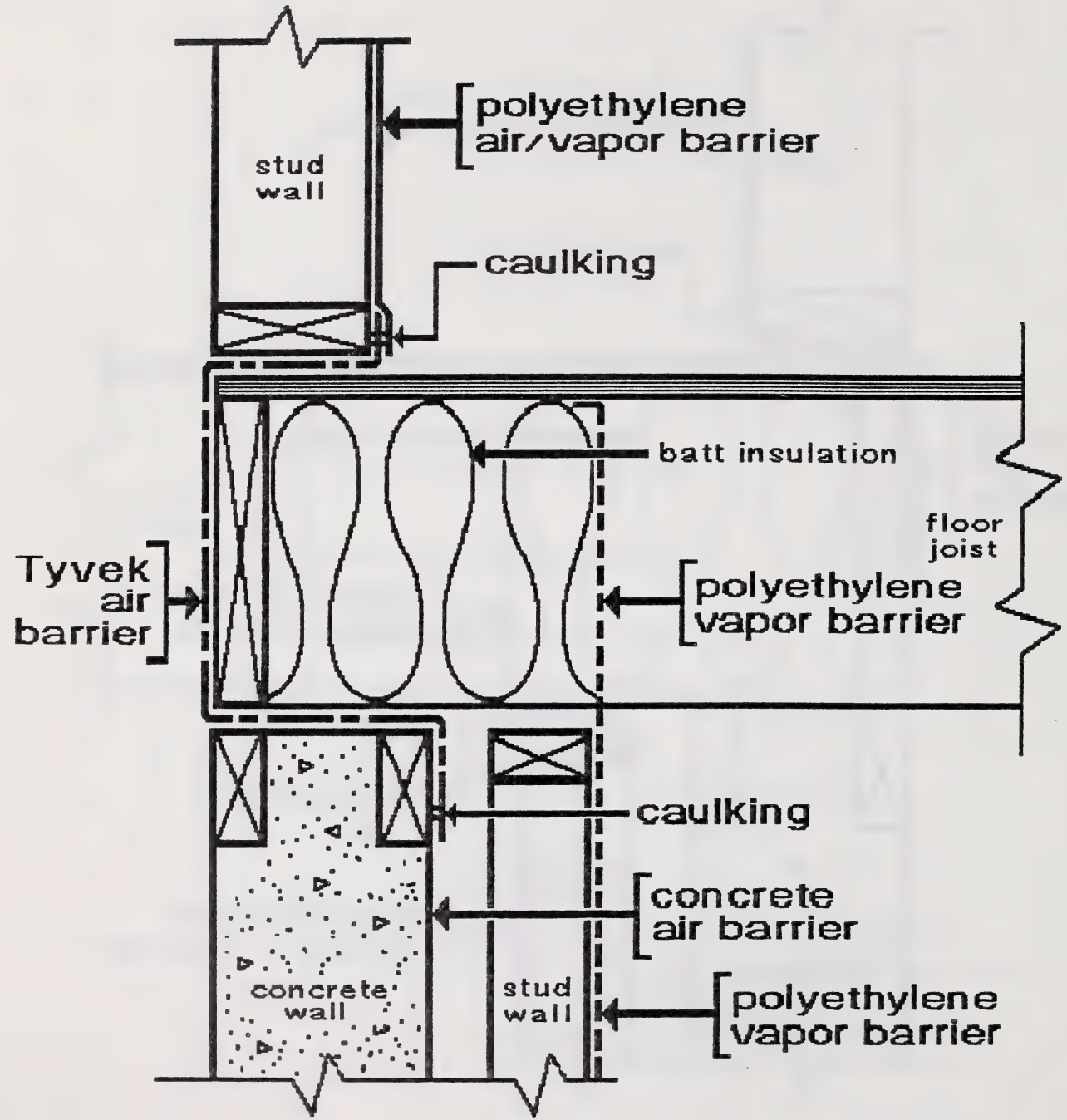

Figure 3: Modification Using Tyvek & Concrete Air Barriers

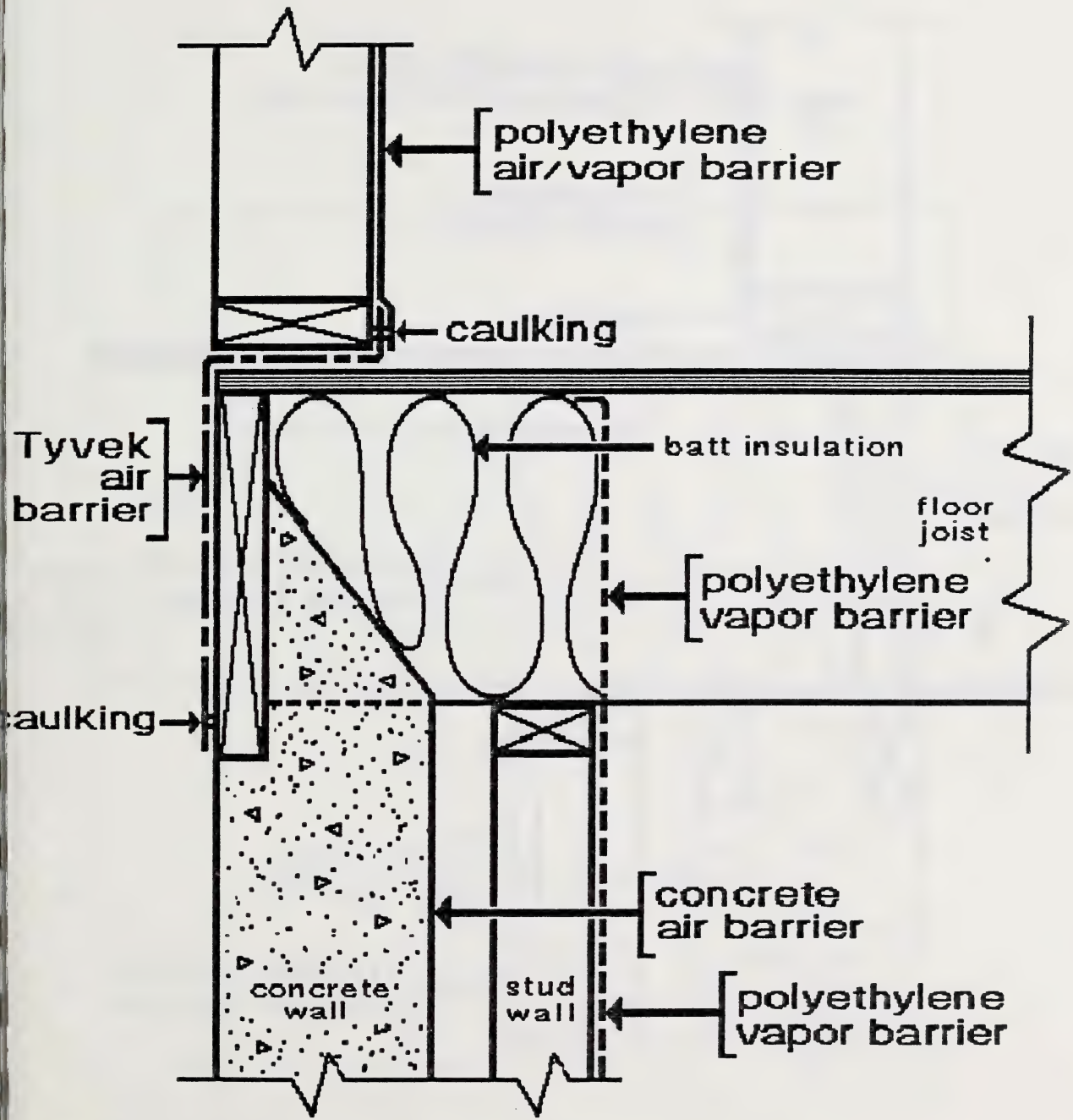

Figure 4: Cast-in-place Joist Using Tyvek & Concrete Air Barriers

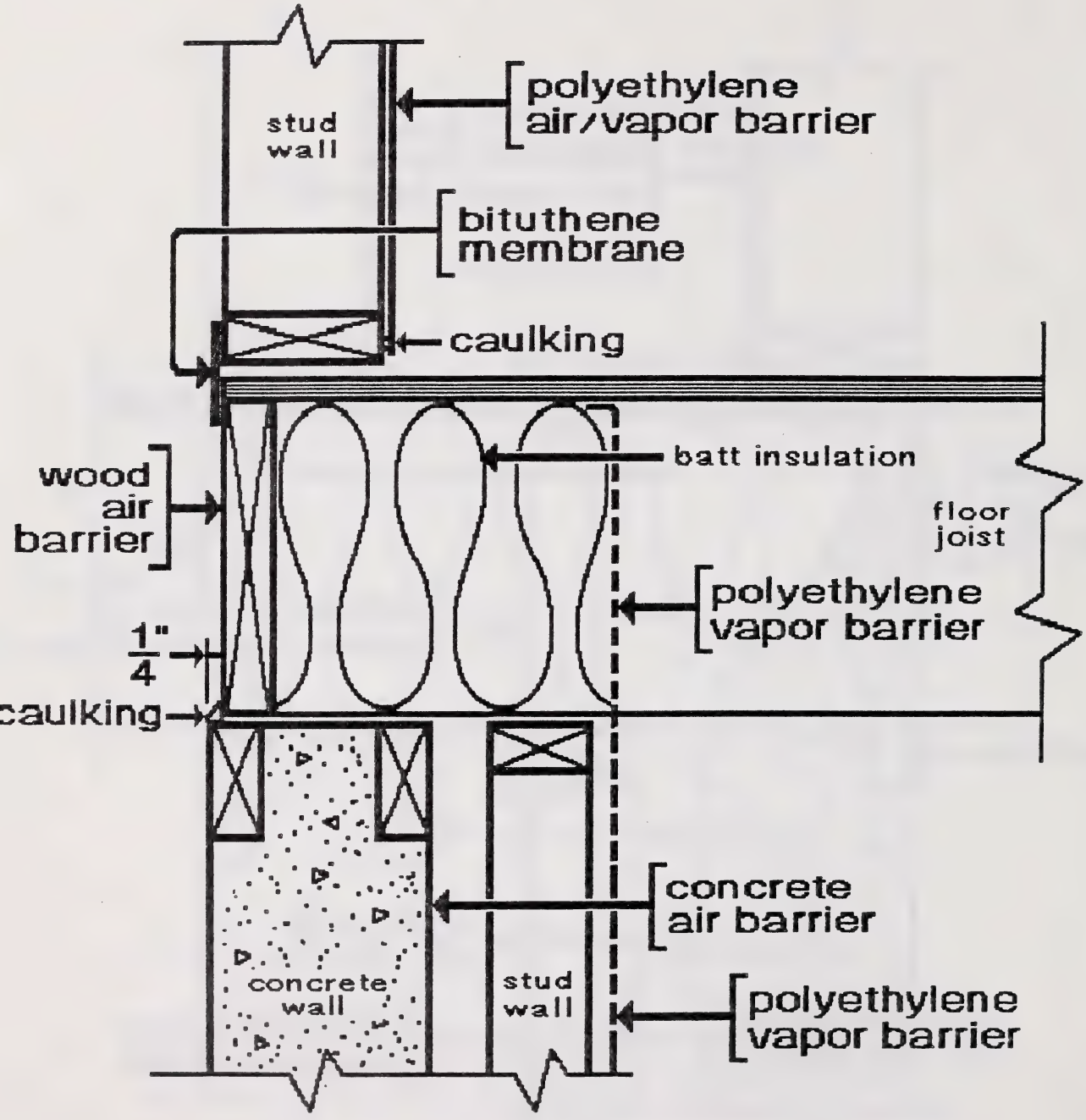

Figure 5: Modification Using Framing Member & Concrete Air Barriers

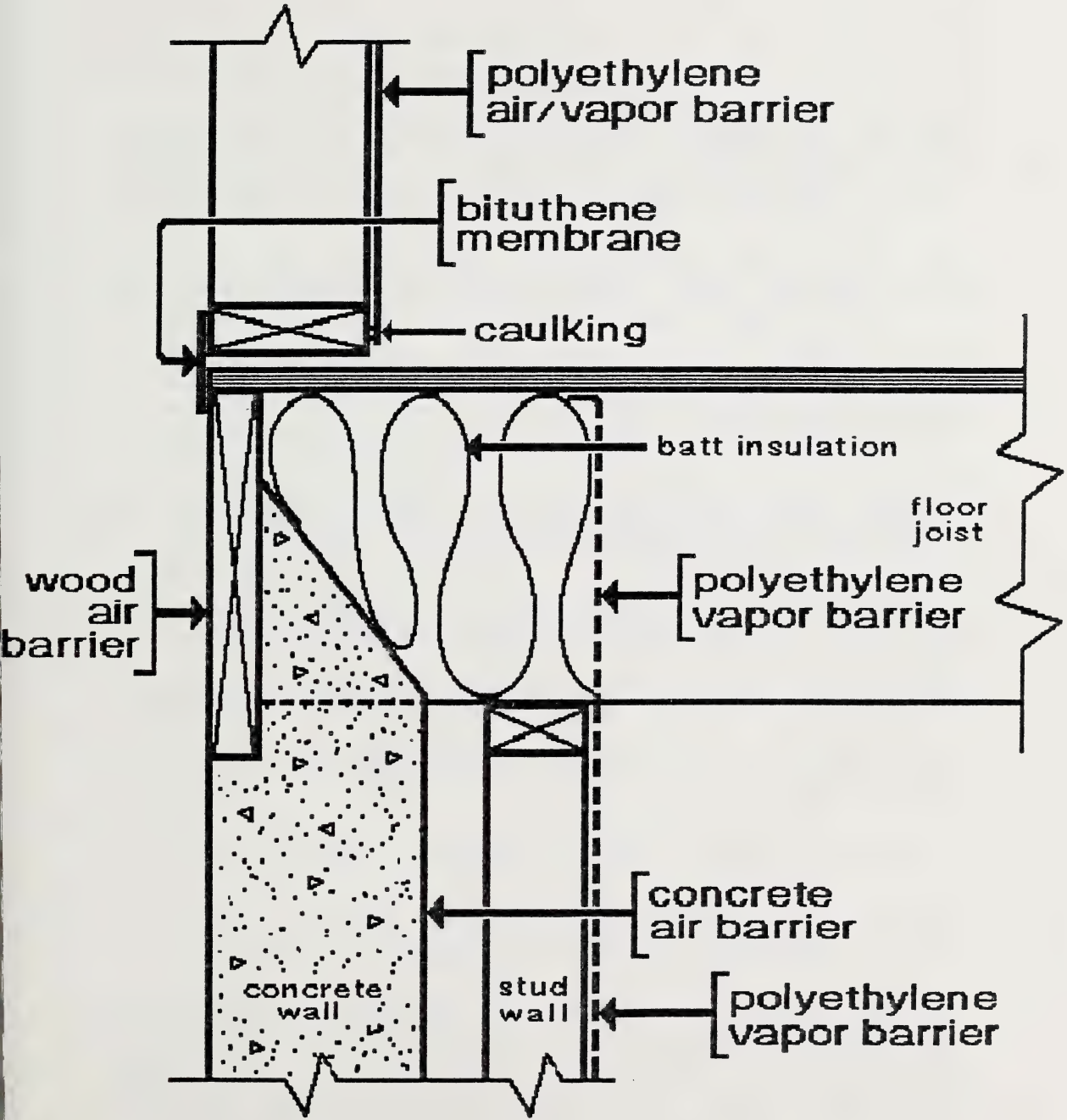

Figure 6: Cast-in-place Joist Using Framing Member & Concrete Air Barriers

9.0 FINDINGS AND RECOMMENDATIONS

9.1 Conventional Building Practices

The R-2000 Program has contributed to changes in the way conventional housing is being built. Building envelope and mechanical system components that were once deemed energy conservation upgrades are now standard features in most houses.

Consider the conventional construction practices of the builders who were interviewed in this study. The following standards were common to the majority of these builders.

1. All of the builders install minimum R-20 exterior walls with a sealed polyethylene air/vapour barrier. Insulated exterior doors are standard. Conventional construction for one Saskatoon builder includes rigid insulation on exterior walls providing R-28 insulation levels.

2. All of the builders, except those in Regina, install batt insulation in their basement walls. Most provide R-12 while the two Saskatoon builders install R-20 as a minimum.

3. All of the builders, except those in Calgary, install at least R-40 blown insulation in the ceiling.

A number of other energy conservation measures have become standard in specific centers.

1. In Saskatoon and Winnipeg, installation of triple glazed windows is the minimum standard in all houses in this study.

2. Three Edmonton builders install medium efficiency furnaces as standard equipment.

3. Three of the four Saskatchewan builders in this study, including the largest builder in Saskatoon, install central exhaust systems in all of their houses.

Based on the information gathered from Prairie builders, it is no longer possible to speak of conventional housing and convey a clear picture of the energy conservation measures incorporated into the conventional house or the construction practices used in building that house. What is considered the conventional housing standard in one center may be the R-2000 standard in another.

9.2 The Optimized R-2000 House

The point has been reached in energy efficient housing in the Prairie Region where the building envelope of an R-2000 house optimized using the HOT-2000 program is almost identical to a conventional house. Typically, to upgrade the building envelope from a conventional to an optimized R-2000 house, a builder need only provide additional care when air sealing and increase basement wall insulation to R-20. The major change in the construction of the optimized R-2000 house occurs with the mechanical system where standard gas-fired space and domestic water heating equipment is replaced with higher efficiency heating equipment and a heat recovery ventilator is installed.

In optimizing the Actual R-2000 houses using the HOT-2000 program, builders soon realized that the relatively small additional investment in a high efficiency HRV compared to a medium efficient unit allowed them to eliminate expensive upgrades such as exterior wall insulation and high performance windows and typically save from $1000 to $2500. Based strictly on cost, the builders considered this type of information extremely valuable because of the competitive nature of their businesses. The builder that has optimized the design of his R-2000 house will incur the lowest incremental costs. The average incremental cost of the optimized R-2000 house, as a percentage of the selling price, was approximately 2.5% in each province.

Realizing the small difference that can exist between a conventional and an optimized R-2000 building envelope, builders spoke of making the optimized R-2000 building envelope their conventional building envelope. Requests for R-2000 houses could then be handled easily by upgrading the mechanical system. Customer-requested upgrades, such as an expanded exterior wall system, would be included in the price of the home as an add-on.

9.3 Maximizing Cost Effectiveness

In addition to optimizing the design of the R-2000 house, consideration should be given to measures that maximize the cost effectiveness of the homeowner's R-2000 investment in the R-2000 house. This involves evaluating fuel types as well as building components. This study has shown that, with the existing natural gas and electricity prices, and, if gas is available, it is not cost effective to use electricity for heating in the Prairie Region. By installing higher efficiency natural gas heating appliances, the following simple payback periods can be achieved.

1. In Alberta, which had the lowest gas prices of the three prairie provinces at approximately $2.70/gigajoule, R-20 basement walls were generally cost effective having a simple payback of 4 to 10 years. Air sealing a medium or large house and providing ventilation with a heat recovery ventilator was marginally cost effective with payback periods of 6 to 10 years. The entire R-2000 package was not cost effective, with payback periods of 15 to over 25 years.

2. In Saskatchewan, where gas prices were approximately $3.40/gigajoule, these figures improved with R-20 basement walls having a simple payback period of 2 to 9 years and controlled ventilation having a payback period of 3 to 7 years. The entire R-2000 package showed payback periods of 5 to 20 years.

3. In Manitoba, where gas prices were approximately $5.30/gigajoule, the entire R-2000 package appeared to be cost effective when simple payback periods were calculated assuming natural gas, rather than electric, heating appliances had been installed. Payback periods ranged from 4 to 13 years in these cases.

Other typical R-2000 components such as exterior walls greater than R-20, attic insulation greater than R-50 and higher performance windows were not cost effective upgrades and should only be considered in order to meet the R-2000 energy target after cost effective measures have been incorporated into the R-2000 design.

9.4 Incremental Cost Analysis

The variations in conventional construction practices in the different cities made it difficult to analyse the gathered data at a regional and, often, provincial level. With different conventional standards existing in each province, there was no common base for comparing R-2000 incremental costs. Each of the R-2000 houses detailed in this report has specific characteristics that often allowed comparisons to be made only between houses that matched those characteristics. When the data was averaged from the municipal to the regional level, it became more generalized and less representative of what is actually happening in each center. The province of Saskatchewan is a prime example of the differences that can exist. Based on the information gathered for this project, the building envelope of a conventional house in Saskatoon would be built to a level of energy efficiency than is equal to, or higher than, an optimized R-2000 house in Regina.

Determining cost effectiveness at a regional and provincial level was also difficult because of the different heating equipment and fuel types used. In Saskatchewan and Manitoba, there was a common base since all of the builders interviewed use standard gas-fired space and water heating equipment in their conventional houses. In Alberta, however, three of the four Edmonton builders install medium efficiency equipment in their conventional houses. As a result, the increased furnace efficiency associated with cost effectiveness for other R-2000 houses in the study cannot be applied to these Edmonton houses.

The situation was complicated further because of variations in the type of energy and heating equipment used in the R-2000 houses. One Alberta builder and four Manitoba builders switched from natural gas in their conventional houses to electricity in their R-2000 houses. In the other R-2000 houses, of the 15 upgraded gas-fired furnaces, six high efficiency units and nine medium efficiency units were installed.

Combined with these variations were the different prices for electricity and natural gas in each region. The cost per gigajoule of electricity is about five times greater than natural gas in Alberta and Saskatchewan and 2.5 times greater in Manitoba.

All of the above factors resulted in averaged energy savings which varied by as much as 40% in a particular city. This wide range emphasizes the need for caution when interpreting and using the averaged figures in this report.

9.5 How Best to Use This Report

This report has not produced definitive incremental cost and cost effectiveness figures that can be applied to the entire Prairie Region. In many of the subject areas, figures cannot be applied in a general, yet accurate, manner at the provincial level and, in some cases, the information is specific to a particular city.

This report can, however, be a valuable document if the reader is willing to take the time to bring together information from different sections of the report that characterize a specific house. The reader wishing to use this document for this purpose should use the following guidelines.

1. Compare the incremental cost and energy savings information detailed for the different building components and choose a set of energy conservation upgrades that best suit a particular budget or

marketplace. Temper all decisions based on cost with a regard for occupant comfort and safety, and building durability.

2. Consider the payback implications of choosing natural gas or electricity as a source of energy by understanding the information presented in Table 18.

3. Choose a builder and house style, using the profile information in Tables 1 and 2, that best represents the specific house of interest and the builder involved.

Those wishing to apply the averaged data to energy efficient housing in general are advised to do so with caution and with a full understanding of the representations being made.

9.6 Recommendations for Future Investigations

If the Prairie Region is an indicator of the direction that energy conservation in housing is taking, then it is no longer possible to choose a broad sample of builders from across Canada and produce incremental costs and cost effectiveness figures that can be applied nationally. This study further indicates that it may not even be possible to produce these costs and figures on a regional basis and, at the provincial level, separate figures may have to be produced for specific centers.

Therefore, before any incremental cost and/or cost effectiveness project is initiated, it is necessary to clearly define the segment of the housing market that is to be studied. Houses should be chosen according to style and size, fuel type and mechanical system upgrades and the conventional house standard in a particular area.

In order to accomplish this, there is a need for a survey of a large number of builders and/or building organizations in order to determine the conventional housing standards that exist across Canada. If energy efficient housing standards are going to be established, it will be important to know the level of energy efficiency that is currently being attained. This work should include an investigation of changes that are expected to occur in conventional housing in the near future as construction practices now considered upgrades are integrated into standard housing practices.

APPENDIX A:

Summary of R-2000 Technical Requirements

SUMMARY OF R-2000 TECHNICAL REQUIREMENTS

1. ENVELOPE

i) Minimum insulation values are specified for exterior above grade walls. This varies with degree day zone from RSI 2.8 (R16) to RSI 4.7 (R27). For example,

RSI 3.6 (R20) is required for Edmonton and south, and
RSI 4.2 (R24) is required for northern Alberta.

ii) Windows must be at least double glazed with 12.5 mm (0.5 in) spacing. Metal frame windows must be thermally broken in most climates.

iii) Airtightness must be not greater than 1.5 ACH at 50 Pa, or not greater than 0.7 cm^2 of leakage area per m^2 of building envelope. (two criteria given to ensure fairness to buildings of different sizes and shapes)

2. VENTILATION SYSTEMS

(similar to CSA F326 preliminary standard)

° Each habitable room must have a specified continuous supply of fresh air. The total continuous fresh air for the house will be between 0.35 and 0.45 ACH.

° Kitchens and bathrooms must be exhausted, either intermittently or continuously. The specified continuous rate is 60% of the intermittent rate.

° Make-up air must be provided such that the exhaust system does not contribute to a pressure difference of more than 10 Pa with continuous operation, or 20 Pa with intermittent operation.

Comment: Although theoretically these requirements could be met with a conventional forced air heating system running continuously in conjunction with exhaust fans in the kitchen and bathrooms, a heat recovery ventilator is a practical necessity to meet the energy target (see p. 2) in the Prairie climate.

3. COMBUSTION EQUIPMENT

° Induced draft or sealed combustion furnaces and water heaters must be used (for efficiency and safety from backdrafting).

° Fireplaces must have tight fitting doors and a combustion air supply from outside.

4. ENERGY PERFORMANCE

° A space and domestic water energy consumption target, calculated using the HOT-2000 computer program, must be met. It varies with the degree-day zone and the heated volume of the house.

° Alternatively, certain prescriptive standards may be used. They are designed to ensure that the house meets the energy consumption target. The minimum standards in Alberta are:

ceilings	R40	Windows	- double glazed, 1/2" air space
main walls	R20	doors	- R8
basement walls	R20	furnace	- 80% efficiency (met by induced draft type)
cantilevers	R28		
basement slab	R0	HWT	- induced draft or sealed combustion
rim joist	R20	HRV	- 60% or better efficiency (met by most standard units)

For houses over 2000 ft^2 (including basement) some of these prescriptive requirements must be increased, based on a specific points system.

5. MISCELLANEOUS REQUIREMENTS

° Builders of R-2000 houses must attend an accredited workshop which includes 21 hours of instruction.
Yearly recertification is required.

° Ventilation system installers must be certified by HRAI.

° A certified R-2000 inspector must inspect the completed house. Airflow measurement stations must be installed so that flow rates of ventilation air can be verified.

APPENDIX B:

Prescriptive Standards

PROCEDURE FOR DETERMINING R-2000 REQUIREMENTS

In order for you as an R-2000 certified builder to enroll and construct a certified R-2000 home you are required to follow one of two methods of determining whether a home meets the minimum R-2000 requirements.

Option 1: HOT 2000 ANALYSIS

You submit a complete package including a full set of working drawings, site plan, window sizes, mechanical specifications to a certified design evaluator. He performs a plan evaluation, inputs the information into the HOT 2000 computer software and the home must then fall under targeted consumption identified by the HOT2000 requirements. This method has been used for the past four (4) years.

Option 2: PRESCRIPTIVE STANDARDS

This method allows you to determine compliance without the need of a plan evaluation and HOT2000 computer analysis.

Please note that if your project has an average basement depth of 48" or less or is greater than 6000 ft² including the basement you cannot use this method. As well if the project has a large percentage of glass the HOT2000 analysis may prove to be more economical.

PRESCRIPTIVE STANDARDS

All units are assumed to start with the following minimum standard

ITEM	MINIMUM R VALUE	ITEM	MINIMUM REQUIREMENTS
Ceilings	R40	Windows	Double Glazed 1/2" air space
Main Walls	R20	Doors	Insulated R8
Bsmt Walls	R20	Furnace	80% EFF
Cantilevers	R28	HWT	Induced draft of Direct vent
Bsmt Slab	R0	HRV	60% or better
Rim Joist	R20		

1. Determine which zone your project is to be built in.

LOCATION	ZONE	LOCATION	ZONE
Calgary	1	Lethbridge	4
Edmonton	2	Rocky Mtn. House	5
Fort McMurray	3	Red Deer, Stettler	

Note: Contact the Regional R-2000 office if your location is not listed.

2. From the house plans determine what size your house is (including basement, for splits take the crawl space area and multiply by .5 if its approximately 4 ft. high).

3. Now using the point chart determine how many points your project needs.

POINT CHART

HOUSE SIZE	ZONE				
	1 CALGARY	2 EDMONTON	3 FT. MCM	4 LETHBRIDGE	5 RED DEER
< -2000	0	0	0	0	0
2001-2500	1	2	2	1	1.5
2501-3000	2	4	4	1	3
3001-3500	2.5	6	6	1.5	4.5
3501-4000	3.0	8	8	2	6
4001-4500	4.5	10	10	3	8
-4500-5000	6.0	12	12	4	10

4. With the required points you can now go to the Point Option Chart on the next page and select the options your customer and you as builder/designer would like to incorporate into the home.

POINT OPTION CHART

OPTION 1: R-25 ABOVE GRADE WALLS (INC. HEADERS)

HOUSE SIZE	ZONES				
	1 Calgary	2 Edmonton	3 Ft. McM.	4 Lethbridge	5 Red Deer
< -2000	0	0	0	0	0
2001-2500	0.40	0.50	.75	0.40	.50
2501-3000	0.75	1.00	1.25	0.75	1.00
3001-3500	1.15	1.25	1.50	0.85	1.25
3501-4000	1.50	1.50	1.75	1.00	1.50
4001-4500	1.75	1.75	2.15	1.35	1.80
4501-5000	2.00	2.00	2.50	1.75	2.10

OPTION 2: TRIPLE GLAZED WINDOWS INCLUDING BASEMENT & GLASS IN DOORS MINIMUM 1/2" AIRSPACE

< -2000	0	0	0	0	0
2001-2500	0.75	0.80	0.85	0.65	0.80
2501-3000	1.50	1.60	1.70	1.30	1.60
3001-3500	1.85	2.05	2.30	1.55	2.10
3501-4000	2.20	2.50	2.90	1.80	2.60
4001-4500	2.40	2.75	3.20	2.05	2.75
4501-5000	2.60	3.00	3.50	2.25	2.90

OPTION 3: 75% OR BETTER HEAT RECOVERY VENTILATOR BASED ON R-2000 APPROVED RATES NOT MANUFACTURES CLAIMS

< -2000	0	0	0	0	0
2001-2500	1.00	1.15	1.40	0.90	1.15
2501-3000	2.00	2.30	2.75	1.75	2.30
3001-3500	2.25	2.75	3.15	2.05	2.65
3501-4000	2.50	3.20	3.50	2.30	3.00
4001-4500	3.15	3.75	4.25	2.90	3.75
4501-5000	3.75	4.30	5.00	3.50	4.50

OPTION 4: R50 CEILING INSULATION INCLUDING VAULTED CEILINGS THIS OPTION REQUIRES HIGH HEEL TRUSSES

ALL SIZES	0.30	0.30	0.30	0.30	0.30

OPTION 5: 90% OR BETTER FURNACE EFFICIENCY

< -2000	0	0	0	0	0
2001-2500	0.75	0.90	1.00	0.75	0.90
2501-3000	1.50	1.75	2.00	1.50	1.75
3001-3500	1.75	2.15	2.50	1.65	2.15
3501-4000	2.00	2.50	3.00	1.75	2.50
4001-4500	2.50	3.00	3.60	2.15	3.00
4501-5000	3.00	3.50	4.20	2.50	3.50

OPTION 6: R28 BASEMENT WALLS FROM RIM JOIST TO T.O. SLAB

HOUSE SIZE	ZONES				
	1 Calgary	2 Edmonton	3 Ft. McM.	4 Lethbridge	5 Red Deer
< -2000	0	0	0	0	0
2001-2500	0.30	0.35	0.40	0.30	0.30
2501-3000	0.60	0.70	0.75	0.60	0.60
3001-3500	0.60	0.70	0.75	0.65	0.65
3501-4000	0.60	0.70	0.75	0.70	0.70
4001-4500	0.65	0.80	0.90	0.75	0.80
4501-5000	0.75	0.90	1.00	0.75	0.90

OPTION 7: LOW E GLAZING DOUBLE PANE MINIMUM 1/2" AIRSPACE

ALL SIZES	0	0.20	0.30	0	0.10

OPTION 8: R7.5 INSULATION UNDER BASEMENT FLOOR 2 FT. WIDE AROUND ENTIRE PERIMETER OF BASEMENT

< -2000	0	0	0	0	0
2001-2500	0.60	0.70	0.70	0.50	0.65
2501-3000	1.20	1.40	1.40	1.00	1.30
3001-3500	1.20	1.40	1.40	1.00	1.30
3501-4000	1.20	1.40	1.40	1.00	1.30
4001-4500	1.40	1.60	1.60	1.15	1.55
4501-5000	1.60	1.80	1.75	1.25	1.75

5. Now identify the options you have decided to incorporate and list them on the "Request For R-2000 Certification Form". Fill in the appropriate builder and home information and send the top copy to the Regional Office and the 2nd copy to the inspector you have chosen for the house.

6. Refer to next page for an example of the procedure.

"R-2000 QUALITY OPTIONS"
SPECIFICATIONS

ZONE I - SOUTH SASKATCHEWAN (REGINA AND AREA)
UP TO 5999 DEGREE DAYS

Ceilings	R50
Walls	R20
Basement Walls	R20
Exposed Floors	R20
Windows	Triple glazed or equivalent
Furnace	Mid Efficient (induced draft)
Hot Water	Induced draft
H.R.V.	60% efficient or better

AIR TEST - by certified air tester
- maximum 1.5 ACH under approved air test procedure

Ventilation equipment installed according to R-2000 guidelines

Builder must be trained at an R-2000 workshop and updated as required.

NOTE:

A builder may choose the alternative of having a certified plan evaluator conduct a detailed analysis of his plans and specs using the approved HOT 2000 program and thereby vary from these specifications.

"R-2000 QUALITY OPTIONS"
SPECIFICATIONS

ZONE II - CENTRAL SASKATCHEWAN (SASKATOON AND AREA)
6000 TO 6499 DEGREE DAYS

Ceilings	R50
Walls	R28
Basement Walls	R20
Exposed Floors	R28
Windows	Triple glazed or equivalent
Furnace	Mid Efficient (induced draft)
Hot Water	Induced draft
H.R.V.	60% efficient or better

AIR TEST - by certified air tester
- maximum 1.5 ACH under approved air test procedure

Ventilation equipment installed according to R-2000 guidelines

Builder must be trained at an R-2000 workshop and updated as required.

NOTE:

A builder may choose the alternative of having a certified plan evaluator conduct a detailed analysis of his plans and specs using the approved HOT 2000 program and thereby vary from these specifications.

"R-2000 QUALITY OPTIONS"
SPECIFICATIONS

ZONE III - NORTH SASKATCHEWAN (PRINCE ALBERT AND AREA)
6500 DEGREE DAYS AND UP

	Ceilings -	R50
	Walls	R28
	Basement Walls	R20
	Exposed Floors	R28
	Windows	Triple glazed or equivalent
*	Furnace	Hi Efficient (condensing)
	Hot Water	Induced draft
*	H.R.V.	60% efficient or better

* A mid-efficient furnace could be used if the H.R.V. is changed to 70% efficient or better.

AIR TEST - by certified air tester
- maximum 1.5 ACH under approved air test procedure

Ventilation equipment installed according to R-2000 guidelines

Builder must be trained at an R-2000 workshop and updated as required.

NOTE:

A builder may choose the alternative of having a certified plan evaluator conduct a detailed analysis of his plans and specs using the approved HOT 2000 program and thereby vary from these specifications.

R-2000 MANITOBA PRESCRIPTIVE STANDARD (Draft #2)

A builder may choose the alternative of having a certified plan evaluator conduct a detailed analysis of his plans and specifications using the approved HOT-2000 program, or this simplified "prescriptive" standard may be followed.

For a particular house to be allowed under the prescriptive method:

- it and its construction must meet the requirements of all applicable local, provincial, and federal codes and statutes, and be in keeping with sound energy-efficient housing design and construction principles.

- it and its construction must meet all other requirements of the R-2000 Program.

- its builder must have been trained at an R-2000 Workshop and have been updated as required.

- it must be located within the province of Manitoba south of latitude 51° 30'. (ie. Churchill)

- it must have a fully heated basement under the entire building, with no crawlspace or slab-on-grade components.

- it must be classifiable as one of the following house types: single-storey, two-storey, or split level.

- it must use electricity or/and natural or propane gas for space and domestic water heating, and the heating appliances must meet the requirements of the R-2000 Program.

    - Electric space heating equipment installed must be rated by the R-2000 Program at a seasonal efficiency of 100%.

    - Gas space heating equipment installed must be rated by the R-2000 Program at a seasonal efficiency of 80% or higher.

- it must meet the minimum airtightness requirements of the R-2000 program (1.5 ach at 50 Pa induced pressure differential).

- its ventilation equipment must be installed and perform according to R-2000 Program minimum requirements.

- its exterior doors must have minimum thermal resistance of R3 (RSI 1.4).

- its windows must be triple-glazed or equivalent, at minimum.

- its exposed floors must have minimum thermal resistance of R27 (RSI 4.7).

- its basement walls must be insulated for the full height.

- its ceiling, main walls, basement walls, and basement floor perimeter thermal resistances (R-values), its space heating system characteristics, and its heat recovery seasonal efficiency on mechanical ventilation must be chosen so that the combination of all these features will provide an acceptably low level of annual space heating and DHW energy consumption for the applicable house type, as follows:

  - For 100 prescriptive combinations which are listed in the attached table of "R-2000 Prescriptive Options", the energy consumption performance has been pre-calculated for each of the 3 house types (single-storey, two-storey, split level). This was done by taking the physical dimensions of groups of actual Manitoba R-2000 one-storey, two-storey, and split level houses built in 1987 and 1988 and applying to them the various combinations of R-values, heating systems, and HRV efficiencies specified in the table. Points have been assigned to each combination on the basis of: (a) how well the entire group would fare against the R-2000 target energy consumption if they were built to the specifications, and (b) what fraction of the houses in the group would fail to meet the target. The points for the 3 house types and all the prescriptive combinations are listed in the table on the right hand side.

  - For any combination listed in the table of options, an increase in R-value of a component, or in seasonal efficiency of heating or heat recovery results in lower energy consumption, and fewer points; conversely, a decrease in R-value or seasonal efficiency results in a higher energy consumption, and more points.

  - The maximum number of points that a house of each type can have and still be eligible for registration in the R-2000 Program has been decided on the basis of: (a) how well the entire group of test houses would fare against the R-2000 target energy consumption if they were built to the specifications, and (b) how far over the target the worst houses in the group would be. The maximum allowable points value for each house type is shown at the bottom of the right hand columns in the table. To be eligible for registration in the R-2000 Program using the prescriptive standard, a house of one of the 3 types (single-storey, two-storey, split level) must have no more than the maximum allowable number of points shown in the table.

  - Example No. 1. Taking the first option in the list, i.e., ceiling R40, walls R20, basement walls R20, no basement floor insulation, electric heat, high-efficiency HRV, we see from the table that its points value is 38 for a bungalow. This qualifies as an R-2000 house because the maximum allowable points for a bungalow is 51. However, if a medium-efficiency HRV were to be used instead of a high-efficiency HRV, then this bungalow would not qualify because its points value would be 68, which is greater than 51.

  - Example No. 2. Neither of the options in Example 1, above, can be used in an R-2000 split level because the points values of 79 and 91 both exceed the allowable, which is 32.

- Example No. 3. To examine a trade-off between additional ceiling insulation and additional basement insulation, we look at two cases: (a) ceiling R43, walls R24, basement walls R28, no basement floor insulation, electric heat, and high-efficiency HRV, and (b) ceiling R60, basement walls R20, and the other components the same as for case (a). For bungalows the points values for the two cases are 16 and 17, respectively. For two-storey houses the points values are 17 and 17, and for split levels they are 52 and 52. These options therefore have nearly the equivalent effect in any of the house types, but only for one- and two-storey houses are the overall packages acceptable R-2000 combinations.

- if the house or its construction cannot meet all of the above criteria then the detailed plan and specification analysis method of registration may be selected.

R-2000 Prescriptive Options - Manitoba Points System

Ceil	R-values Main Walls	R-values Bas't Walls	R-values Bas't Floor 1 m Perim	Heating System	HRV Seasonal Efficiency High (77 %) House type One	High (77 %) House type Two	High (77 %) House type Split	HRV Seasonal Efficiency Medium (65 %) House type One	Medium (65 %) House type Two	Medium (65 %) House type Split
45	20	20	0	G-Mid or E	36	45	79	68	74	91
			0	G-High	15	16	51	30	32	77
			5	G-Mid or E	18	23	70	45	70	81
		24	0	G-Mid or E	27	40	78	62	72	90
			5	G-Mid or E	16	19	63	32	59	80
		28	0	G-Mid or E	22	29	77	56	72	84
			5	G-Mid or E	14	18	57	23	46	74
	24	20	0	G-Mid or E	24	19	69	56	57	81
			5	G-Mid or E	15	15	45	25	27	71
		24	0	G-Mid or E	17	18	63	40	48	79
			0	G-High	13	12	31	18	19	62
			5	G-Mid or E	12	14	33	20	23	70
		28	0	G-Mid or E	16	17	52	36	40	78
			5	G-Mid or E	11	12	32	17	19	63
	27	20	0	G-Mid or E	21	16	46	40	35	78
			5	G-Mid or E	12	12	32	22	19	63
		24	0	G-Mid or E	16	15	45	34	29	76
			0	G-High	9	8	22	15	14	38
			5	G-Mid or E	11	11	30	17	18	52
		28	0	G-Mid or E	15	14	44	25	25	71
			5	G-Mid or E	9	10	24	15	17	45
60	20	20	0	G-Mid or E	26	29	77	60	72	84
			5	G-Mid or E	15	19	63	31	54	79
		24	0	G-Mid or E	20	28	71	50	71	82
			5	G-Mid or E	13	17	46	21	40	73
		28	0	G-Mid or E	17	20	70	37	70	82
			5	G-Mid or E	12	16	45	19	30	71
	24	20	0	G-Mid or E	17	17	52	38	40	79
			5	G-Mid or E	12	14	33	21	23	69
		24	0	G-Mid or E	15	16	46	30	35	77
			5	G-Mid or E	10	12	31	16	19	52
		28	0	G-Mid or E	14	15	45	23	29	71
			5	G-Mid or E	9	11	30	15	18	46
	27	20	0	G-Mid or E	15	14	44	30	23	71
			5	G-Mid or E	10	11	30	17	17	46
		24	0	G-Mid or E	13	13	33	23	22	69
			5	G-Mid or E	8	9	23	14	16	45
		28	0	G-Mid or E	12	13	32	19	19	63
			0	G-High	5	6	20	11	12	31
			5	G-Mid or E	7	8	22	17	15	33
			5	G-High	0	2	10	6	8	21
30	20	20	0	G-Mid or E	64	63	84	81	82	93
			0	G-High	24	29	70	38	57	81
			5	G-Mid or E	38	47	79	63	76	91
		28	0	G-Mid or E	47	57	82	73	80	93
			5	G-Mid or E	19	28	71	51	71	82
	27	20	0	G-Mid or E	33	20	76	68	62	87
			5	G-Mid or E	19	16	46	47	35	78
		28	0	G-Mid or E	23	18	63	53	44	80
			5	G-Mid or E	14	14	38	23	23	70
R-2000 Program Maximum Allowable Points:					51	52	52	51	52	32

APPENDIX C:

Quantity Surveyor Verification

INCREMENTAL COST OF UPGRADING STANDARD DESIGN TO R-2000 DESIGN COMPARED TO QUANTITY SURVEYOR ESTIMATES

Builder/House Number	Northern Alberta Edmonton 1	*1QS*	2a	*2aQS*	2b	*2bQS*	3a	*3aQS*	3b	*3bQS*	4a	*4aQS*	4b	*4bQS*
STANDARD HOUSE COST	103000	*103000*	110340	*110340*	92700	*92700*	52844	*52844*	86360	*86360*	90100	*90100*	127200	*127200*
Incremental Cost Of Actual R-2000 House														
Building Envelope														
Slab/Foundation	0	*0*	652	*453*	0	*0*	451	*409*	149	*150*	0	*0*	480	*479*
Basement Walls	181	*168*	170	*149*	163	*150*	165	*140*	174	*155*	146	*117*	182	*146*
Rim Joist	785	*561*	657	*487*	288	*319*	228	*224*	343	*389*	0	*0*	0	*0*
Cantilevers	0	*0*	0	*0*	0	*0*	23	*18*	17	*22*	0	*0*	0	*0*
Exterior Walls	0	*0*	1100	*1248*	548	*540*	700	*722*	654	*845*	1495	*1495*	2234	*2234*
Attic/Roof	0	*0*	448	*447*	306	*331*	115	*144*	143	*161*	135	*108*	225	*180*
Windows	1750	*1250*	300	*422*	150	*300*	589	*512*	970	*807*	1172	*1030*	1171	*1048*
Exterior Doors	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Air Sealing	428	*530*	370	*200*	300	*200*	170	*200*	52	*200*	50	*100*	75	*100*
Sub-total	3144	*2509*	3697	*3406*	1755	*1840*	2441	*2369*	2502	*2729*	2998	*2850*	4367	*4187*
Mechanical System														
Space Heating	1700	*1500*	0	*0*	0	*0*	0	*0*	60	*0*	0	*0*	0	*0*
Water Heating	420	*400*	400	*400*	400	*400*	420	*400*	420	*400*	500	*400*	500	*400*
Ventilation Equipment	1380	*1468*	1670	*1527*	1700	*1717*	1385	*1368*	1430	*1407*	1300	*1350*	1300	*1350*
Sub-total	3500	*3368*	2070	*1927*	2100	*2117*	1805	*1768*	1910	*1807*	1800	*1750*	1800	*1750*
Other Costs														
Air test	180	*200*	200	*200*	200	*200*	200	*200*	200	*200*	180	*200*	180	*200*
Supervision	200	*0*	200	*0*	200	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Administration	0	*0*	500	*0*	500	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Sub-total	380	*200*	900	*200*	900	*200*	200	*200*	200	*200*	180	*200*	180	*200*
ACTUAL INCRE. COSTS	7024	*6077*	6667	*5533*	4755	*4157*	4446	*4337*	4612	*4736*	4978	*4900*	6347	*6137*
TOTAL COSTS	110024	*109077*	117007	*115873*	97455	*96857*	57290	*57181*	90972	*91096*	95078	*94900*	133547	*133337*
% INCREMENTAL COSTS	6.4%	*5.6%*	5.7%	*4.8%*	4.9%	*4.3%*	7.8%	*7.6%*	5.1%	*5.2%*	5.2%	*5.1%*	4.8%	*4.6%*

INCREMENTAL COST OF UPGRADING STANDARD DESIGN TO R-2000 DESIGN COMPARED TO QUANTITY SURVEYOR ESTIMATES

	Southern Alberta Red Deer		Calgary									
Builder/House Number	5a	*5aQS*	5b	*5bQS*	6a	*6aQS*	6b	*6bQS*	7a	*7aQS*	7b	*7bQS*
STANDARD HOUSE COST	67000	*67000*	69400	*69400*	105847	*105847*	81540	*81540*	36200	*36200*	69000	*69000*
Incremental Cost Of Actual R-2000 House												
Building Envelope												
Slab/Foundation	0	*0*	0	*0*	0	*0*	0	*0*	196	*217*	272	*302*
Basement Walls	61	*39*	0	*0*	201	*161*	151	*121*	274	*193*	456	*477*
Rim Joist	0	*0*	0	*0*	150	*150*	170	*170*	146	*111*	224	*188*
Cantilevers	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Exterior Walls	0	*0*	0	*0*	2232	*2349*	1529	*1495*	241	*253*	478	*518*
Attic/Roof	0	*0*	0	*0*	187	*204*	227	*294*	358	*283*	419	*430*
Windows	663	*605*	698	*647*	140	*275*	120	*275*	123	*200*	717	*754*
Exterior Doors	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Air Sealing	435	*458*	314	*400*	612	*450*	622	*450*	311	*350*	386	*350*
Sub-total	1159	*1102*	1012	*1047*	3522	*3589*	2819	*2805*	1649	*1607*	2952	*3019*
Mechanical System												
Space Heating	500	*500*	500	*500*	500	*500*	500	*500*	-460	*-460*	500	*500*
Water Heating	600	*400*	600	*400*	450	*400*	450	*400*	0	*0*	450	*400*
Ventilation Equipment	1110	*1468*	1110	*1468*	1550	*1527*	1470	*1527*	1080	*1368*	1195	*1407*
Sub-total	2210	*2368*	2210	*2368*	2500	*2427*	2420	*2427*	620	*908*	2145	*2307*
Other Costs												
Air test	200	*200*	200	*200*	200	*200*	200	*200*	350	*200*	350	*200*
Supervision	42	*0*	42	*0*	160	*0*	160	*0*	0	*0*	0	*0*
Administration	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Sub-total	242	*200*	242	*200*	360	*200*	360	*200*	350	*350*	350	*350*
ACTUAL INCRE. COSTS	3611	*3670*	3464	*3615*	6382	*6216*	5599	*5432*	2619	*2865*	5447	*5676*
TOTAL COSTS	70611	*70670*	72864	*73015*	112229	*112063*	87139	*86972*	38819	*39065*	74447	*74676*
% INCREMENTAL COSTS	5.1%	*5.2%*	4.8%	*5.0%*	5.7%	*5.5%*	6.4%	*6.2%*	6.7%	*7.3%*	7.3%	*7.6%*

INCREMENTAL COST OF UPGRADING STANDARD DESIGN TO R-2000 DESIGN COMPARED TO QUANTITY SURVEYOR ESTIMATES

	Saskatchewan Regina		Saskatoon													
Builder/House Number	8a	*8aQS*	8b	*8bQS*	9a	*9aQS*	9b	*9bQS*	10a	*10aQS*	10b	*10bQS*	11a	*11aQS*	11b	*11bQS*
STANDARD HOUSE COST	112900	*112900*	102800	*102800*	72900	*72900*	81200	*81200*	64400	*64400*	140600	*140600*	53890	*53890*	91830	*91830*
Incremental Cost Of Actual R-2000 House																
Building Envelope																
Slab/Foundation	100	*70*	100	*70*	0	*0*	0	*0*	0	*0*	0	*0*	197	*273*	0	*0*
Basement Walls	1754	*1402*	1397	*1121*	1210	*972*	1382	*1475*	0	*0*	0	*1475*	0	*0*	0	*1475*
Rim Joist	137	*130*	0	*0*	100	*100*	105	*105*	0	*0*	0	*105*	0	*0*	0	*105*
Cantilevers	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Exterior Walls	1925	*1925*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	309	*518*	585	*892*
Attic/Roof	500	*413*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	255	*336*	271	*441*
Windows	1000	*1000*	763	*1271*	432	*215*	524	*379*	0	*0*	0	*379*	100	*150*	100	*300*
Exterior Doors	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Air Sealing	430	*350*	320	*450*	221	*450*	292	*350*	250	*450*	250	*450*	250	*450*	250	*450*
Sub-total	5846	*5290*	2580	*2912*	1963	*1737*	2303	*2309*	250	*450*	250	*2409*	1111	*1727*	1206	*3663*
Mechanical System																
Space Heating	600	*500*	1800	*2000*	1340	*1000*	1265	*1000*	1500	*1000*	1500	*1000*	350	*500*	350	*500*
Water Heating	500	*400*	500	*400*	515	*400*	515	*400*	450	*400*	450	*400*	0	*0*	0	*0*
Ventilation Equipment	1000	*1250*	1350	*1440*	1450	*1468*	1500	*1468*	1276	*1250*	1275	*1250*	1200	*1250*	1200	*1250*
Sub-total	1100	*900*	2300	*2400*	1855	*1400*	1780	*1400*	1950	*1400*	1950	*1400*	350	*500*	350	*500*
Other Costs																
Air test	150	*200*	150	*200*	150	*200*	150	*200*	150	*200*	150	*200*	150	*200*	150	*200*
Supervision	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	100	*0*	100	*0*
Administration	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Sub-total	150	*350*	150	*350*	150	*350*	150	*350*	150	*350*	150	*350*	250	*350*	250	*350*
ACTUAL INCRE. COSTS	7096	*6540*	5030	*5662*	3968	*3487*	4233	*4059*	2350	*2200*	2350	*4159*	1711	*2577*	1806	*4513*
TOTAL COSTS	119996	*119440*	107830	*108462*	76868	*76387*	85433	*85259*	66750	*66600*	142950	*144759*	55601	*56467*	93636	*96343*
% INCREMENTAL COSTS	5.9%	*5.5%*	4.7%	*5.2%*	5.2%	*4.6%*	5.0%	*4.8%*	3.5%	*3.3%*	1.6%	*2.9%*	3.1%	*4.6%*	1.9%	*4.7%*

INCREMENTAL COST OF UPGRADING STANDARD DESIGN TO R-2000 DESIGN COMPARED TO QUANTITY SURVEYOR ESTIMATES

Builder/House Number	Manitoba Winnipeg 12a	*12aQS*	12b	*12bQS*	13	*13QS*	14a	*14aQS*	14b	*14bQS*	15a	*15aQS*	15b	*15bQS*
STANDARD HOUSE COST	91000	*91000*	115000	*115000*	110400	*110400*	61200	*61200*	63860	*63860*	105000	*105000*	97600	*97600*
Incremental Cost Of Actual R-2000 House														
Building Envelope														
Slab/Foundation	0	*0*	395	*396*	0	*0*	0	*0*	0	*0*	595	*448*	48	*45*
Basement Walls	0	*0*	900	*822*	200	*128*	286	*149*	238	*154*	1138	*1085*	1018	*1155*
Rim Joist	0	*0*	0	*0*	400	*392*	125	*125*	125	*125*	122	*153*	89	*89*
Cantilevers	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Exterior Walls	0	*0*	944	*944*	0	*0*	0	*0*	0	*0*	2102	*1966*	1324	*1251*
Attic/Roof	0	*0*	175	*161*	0	*0*	0	*0*	69	*30*	278	*288*	290	*373*
Windows	0	*0*	285	*225*	0	*0*	0	*0*	0	*0*	312	*300*	572	*654*
Exterior Doors	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Air Sealing	0	*0*	0	*0*	0	*0*	350	*350*	350	*350*	250	*350*	250	*250*
Sub-total	0	*0*	2699	*2548*	600	*520*	761	*624*	782	*659*	4797	*4590*	3591	*3817*
Mechanical System														
Space Heating	5549	*5549*	1076	*1076*	200	*500*	475	*475*	475	*475*	-345	*-345*	-335	*-335*
Water Heating	0	*0*	0	*0*	-60	*-60*	0	*-60*	0	*-60*	0	*0*	0	*0*
Ventilation Equipment	1650	*1475*	1650	*1475*	1300	*1582*	1092	*1432*	1618	*1587*	2195	*2195*	2045	*2195*
Sub-total	5549	*5549*	1076	*1076*	140	*440*	475	*415*	475	*415*	-345	*-345*	-335	*-335*
Other Costs														
Air test	110	*200*	110	*200*	75	*200*	125	*200*	125	*200*	150	*200*	150	*200*
Supervision	0	*0*	0	*0*	0	*0*	30	*0*	30	*0*	30	*0*	30	*0*
Administration	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*	0	*0*
Sub-total	110	*350*	110	*350*	75	*350*	155	*350*	155	*350*	180	*350*	180	*350*
ACTUAL INCRE. COSTS	5659	*5899*	3885	*3974*	815	*1310*	1391	*1389*	1412	*1424*	4632	*4595*	3436	*3832*
TOTAL COSTS	96659	*96899*	118885	*118974*	111215	*111710*	62591	*62589*	65272	*65284*	109632	*109595*	101036	*101432*
% INCREMENTAL COSTS	5.9%	*6.1%*	3.3%	*3.3%*	.7%	*1.2%*	2.2%	*2.2%*	2.2%	*2.2%*	4.2%	*4.2%*	3.4%	*3.8%*